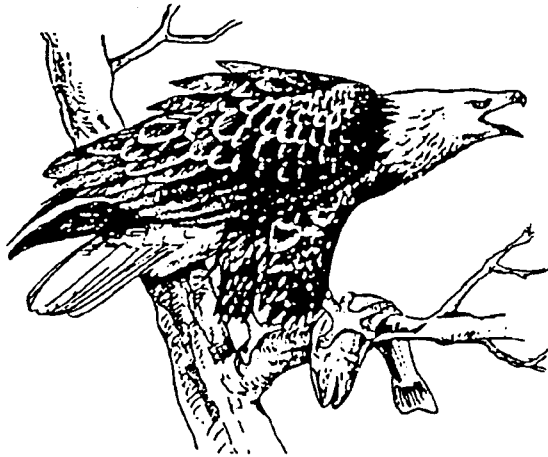


PROPOSED NEW MADRID NWR

CONTAMINANT SURVEY

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Region 3

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INTRODUCTION

Area Description

The study area is near New Madrid in southeast Missouri. This area consists of the St. John's Bayou, 8,500 acres and Eagle's Nest area, 3,500 acres. These adjoining areas comprise (at the time this study was initiated) the proposed Fish and Wildlife Service (FWS) acquisition for a new National Wildlife Refuge. Both areas are influenced by larger watersheds: St. John's Bayou lies at the outlet of St. John's Basin, 289,000 acres; Eagle's Nest lies at the outlet of the New Madrid Floodway, 117,000 acres. The project area is located north of Reelfoot Lake which is on the Tennessee side of the Mississippi River. The project area is a designated wetland, presently about 70 percent is farmed. The primary crop is soybeans.

The area is level to nearly level. Alterations for farming have eliminated most evidence of old sloughs and ponds that once existed. This area is in a basin having high ground around the east and west sides. Most of the area is very low and flood prone. Levees offer flood protection except when water levels are extremely high. Backwater flooding, caused by high Mississippi River stages covers most of the proposed refuge every winter.

Eight soil types are found on the study area. The area is nearly level and poorly drained with soils that are typical of slack water areas along the Mississippi floodplain.

This area historically was seasonally flooded lowland hardwood forest with cypress-tupelo sloughs. This area once was a paradise for wintering waterfowl, furbearers, and other wildlife species indigenous to this habitat type. However, increased drainage, access development, and the use of more efficient logging and clearing equipment caused a rapid conversion to agricultural land.

Relationship to Other Studies

A restoration project presently exists at Reelfoot Lake to enhance nesting for bald eagles. During the annual Christmas bird count in 1988, four bald eagles were observed in Mississippi County, and seven bald eagles were observed in 1989. This indicates increased bald eagle usage in the area. Summering bald eagles have also been observed in the project area and bald eagle nesting attempts were made at Donaldson Point State Forest in Missouri.

The Missouri Department of Conservation owns Ten Mile Pond and adjacent lands. These lands are being intensively managed for waterfowl usage.

A site visit was conducted in May 1988 by the CMFO contaminant biologist. Several illegal dumps were located in just one cursory survey. One of the dumps was approximately one acre in size. A drive through of the area in early 1989 revealed that several of these dumps had increased in size. These unauthorized waste disposal sites could be a source of contamination to the study area. Man applied chemicals are a potential threat to fish and wildlife in the study area. The study area being located at the outlet of two large intensively

farmed basins increases the likelihood of contaminant concentrations. The proposed Corps of Engineers (COE) project to close the lower outlet for the New Madrid Floodway may increase contaminant buildup and uptake in the food chain.

Methods

Collections for fish were attempted at all sites. Seining, gill netting, and electro-shocking methods were utilized. These were continued until adequate samples were obtained or sampling time ran out. When selecting fish from the nets, preference was given to those species that tend to be high in fat, such as carp, buffalo, and catfish. Each fish was weighed to the nearest 0.10 gram and total length was measured to the nearest millimeter. Each fish was then individually wrapped in foil, labeled and continuously stored on ice in a cooler until returning to CMFO. The specimens then were frozen solid in a chest style freezer unit. Eventually, they were shipped in coolers with dry ice to the appropriate contract laboratory for analysis. The shipment was accompanied by a catalog containing instructions, types of analysis, and specific sample information, see Appendix F.

Sediment samples were collected in the general vicinity of each sample site. They were obtained by using an Ekman dredge or by hand using a stainless steel spoon, depending on water depth. The sediment samples were placed in chemically cleaned jars and were stored and shipped along with the fish samples.

Laboratory Methods

An atomic absorption (AA) spectrophotometer technique was used for measuring levels of Arsenic, Mercury, and Selenium. All other metals (Aluminum, Barium, Beryllium, Boron, Cadmium, Chromium, Cobalt, Copper, Iron, Lead, Magnesium, Manganese, Molybdenum, Nickel, Silver, Strontium, Tin, Vanadium, and Zinc) were detected with an inductively coupled plasma atomic emission spectrophotometer (ICP).

Chemical analysis for organochlorines (AlphaBHC, AlphaChlordane, BetaBHC, CisNonachlor, DDD24OP_, DDD44PP_, DDE24OP_, DDE44PP_, DT24OP_, DDT44PP_, DelBHC, Dieldrin, Endrin, GammaChlordane, HCB, HeptaEpoxide, Lindane_GammaBHC, Mirex, OxyChlordane, PCBtotal, Toxaphene, TransNonachlor) was accomplished by gas-liquid chromatography after extraction, gel permeation chromatography cleanup, and silica gel chromatography separation.

The Research Triangle Institute in North Carolina performed the analyses for metals and the Mississippi State Chemical Laboratory at Mississippi State University performed the analyses for organics. These laboratories are under contract to the U.S. Fish and Wildlife Service and were subjected to a rigorous evaluation process prior to the award of their contracts. The Patuxent Analytical Control Facility of the U.S. Fish and Wildlife Service closely monitors the performance of these laboratories during analysis and has confidence in the

accuracy of the data. Acceptable performance on spikes, blanks, and duplicates was documented in laboratory quality control reports.

Discussion

Sample Collection Locations

The actual sample collection locations are indicated in Appendix D Map 1. Locations were picked prior to going in the field. Some of these were changed due to access problems or lack of collections. The locations are spread over the proposed refuge area with sample points where water enters the area and where it leaves. These were picked to see if there was any difference that might indicate potential locations of contaminants. Sediments were collected at all locations except number 5. Collections for fish were attempted at all locations. Fish were obtained from locations number 3, 4, and 5. Location 5 was chosen on the last day of collections just prior to leaving due to the lack of success at the other pre-chosen locations.

Contaminant Concentration Comparisons

It is not a simple task to accurately measure concentrations of contaminants in tissues of fish and wildlife. However, once the concentrations have been correctly measured, it is sometimes even more difficult to determine what these concentrations mean to the well-being of the organism or to predatory species of fish and wildlife which may consume the organism. Detailed information on this subject is sparse [1].

There are no uniformly accepted standards for tolerable tissue concentrations of contaminants which will protect fish and wildlife and the predators which consume them. Instead, there is a hodgepodge of action and alert levels proposed by various agencies and experts for specific rather than uniform applications [1].

Some of these action or alert levels are based on fillet (edible to humans) samples, while others are based on whole-body samples. Some relate to fish only. For the contaminants which have been relatively extensively studied, like PCB's, we have many action or alert levels for comparison with our residue data. Very few or no alert levels for fish and wildlife residues have been proposed for many other contaminants, especially those contaminants whose effects have not been well publicized or studied. Therefore, we know less about the potential meaning of these residue values [1].

After an extensive literature review and consulting with numerous Service experts, chemists, toxicologists, and biologists basically two data sets were selected for contaminant comparison of background or threshold levels (see Appendix F). The first one is the National Contaminant Biomonitoring Program (NCBP) which is maintained by the U.S. Fish and Wildlife Service (FWS) documenting temporal and geographic trends in concentrations of persistent environmental contaminants that may threaten fish and wildlife [2]. The second

one is the basin specific background levels of chemicals present in the sediments of the Great Lakes as presented in the Procedures for the Assessment of Contaminated Sediment Problems in the Great Lakes (IJC).

Results

Various contaminants were detected at all sites where sediments were collected. These are shown in Appendix D Map 2. Each contaminant detected is listed at the sites where they were found. Various contaminants were also detected at all sites where fish were collected. These are shown in Appendix D Map 3. The rest of the maps in Appendix D list the levels of contaminants discovered at each location with a separate map for each contaminant.

The complete report of the sample analyses for both organochlorines and metals is included in Appendix B and C respectively.

Actual collections occurred in April and May of 1990. A total of 27 sediment samples were collected and 13 fish samples were collected. A table relating the sample number to the site location number is located in Appendix D.

Metals were detected in all the sediment and all the fish samples. Metals that were found in sediments above the laboratory detection limits were Aluminum, Arsenic, Barium, Beryllium, Boron, Cadmium, Chromium, Cobalt, Copper, Iron, Lead, Magnesium, Manganese, Mercury, Nickel, Selenium, Strontium, Vanadium, and Zinc. Metals that were found in fish above the laboratory detection limits were Aluminum, Barium, Boron, Cadmium, Chromium, Copper, Iron, Lead, Magnesium, Manganese, Mercury, Nickel, Selenium, Strontium, Tin, Vanadium, and Zinc.

Organochlorines were detected in all of the fish samples. Organochlorines that were found in fish above the laboratory detection limits were AlphaChlordane, CisNonachlor, DDD, DDE, DDT, Dieldrin, GammaChlordane, PCB's, Toxaphene, TransNonachlor.

Metals

Metals occur in natural waters in trace amounts. Since metals are used extensively in many industrial processes, they are usually present in a variety of effluents entering ground and surface waters. Reisinger (1980) [3] notes that while some metals are essential to aquatic biota in trace amounts, the concentrations found in metal-enriched ecosystems are potentially harmful. Under some conditions, metals in suspension are toxic to fish, but in general it is the metallic ion in solution which exhibits toxicity to living organisms. Organisms exposed to sublethal metal concentrations have shown increased tolerance in subsequent exposures [4] [5].

Dissolved organic matter (DOM) plays a significant role in the distribution, transport and fate of heavy metals in aquatic systems. Dissolved organics are capable of complexing

metals and increasing solubility; altering distribution between oxidized and reduced forms; and influencing the extent to which metals are absorbed on suspended matter. When metals are present in small amounts, DOM can make the metal either more or less available to an organism. However, the toxic effects of metals present in high concentrations can be alleviated by DOM [6][5].

When an aquatic food chain is contaminated, bioconcentration, bioaccumulation and biomagnification can occur. Metals entering an organism will be transported to organs ("target organs") for which a particular metal has an affinity. In aquatic organisms, an equilibrium mechanism appears to regulate metal uptake, and once equilibrium has been reached, body or organ concentrations will shift only with a shift in source concentration [3] [5].

The incorporation of metals into fish can occur along two pathways: absorption across gill surfaces and through the gut wall. Investigations [7] suggest that the gastrointestinal route becomes less important as an aquatic ecosystem becomes progressively contaminated with metals. There is experimental evidence [7] which demonstrates homeostatic regulation of calcium, magnesium and zinc in fish, suggesting that fish are of decreased value for monitoring metals when body concentration are independent of ambient concentrations and should be used for monitoring only for metals known to accumulate with exposure [5].

Many external factors influence the absorption and toxicity of metals to fish. These factors include the nature and concentration of the metal, its valence, the form of the metal in water, presence of other metals, Ph, volume of water, time and duration of exposure, water temperature, dissolved oxygen levels and the feeding habits and physical condition of the fish. In addition, experimental evidence indicates that species differences exist among fish with respect to their ability to concentrate metals. Metal concentrations that have been reported in the literature are often contradictory with wide variations for a particular metal both within and between species. This phenomenon clouds the relationship between tissue concentration and toxicity. He recommends that monitoring programs for metals in fish populations adopt a standard protocol which incorporates a rationale for specimen selection based on a consideration of factors which influence metal bioaccumulation [5].

Aluminum

(Al, Chemical Abstract Service, CAS, Registry Number: 7429-90-5)

The following is taken from the Contaminant Encyclopedia, which is currently under development by Roy J. Irwin, USFWS [8]:

Aluminum is a light silvery-white metal with an atomic number of 13 and a atomic weight 26.9815 [9]. Aluminum in natural waters appears in a wide array of forms, including organic complexes, fluoride complexes, and aluminum hydroxide [10]. Aluminum is the third most abundant element (8%) in the Earth's crust, exceeded by oxygen (47%) and

silicon (28%). Because of its strong affinity to oxygen, aluminum never occurs as a metal in nature but is found only in the form of its compounds, mostly oxides or silicates [9].

The toxicity of aluminum depends on how it is complexed [10]. For example, organically-bound forms of aluminum generally are less toxic than the inorganic forms [10]. The specification of aluminum is pH-dependent, and higher aluminum toxicities also occur at lower pH levels. Because of the many species of aluminum found in water, the precise relationships of aluminum concentrations to toxicity still are not well understood [10].

Aluminum has been implicated as a neurotoxic agent in a number of studies [11] [12] [13]. A primary mechanism for aluminum-induced toxicity is free-ion aluminum (Al^{3+}) substitution for magnesium at critical enzyme sites and resultant depressions in magnesium-dependent functions [14]. Aluminum concentrations in living organisms tend to be low, but citrate or other acidic mediums can increase aluminum uptake [15].

Much research related to human health is now being undertaken to determine how much of a role aluminum plays in neurological problems such as Alzheimer's disease [11] and aluminum has been shown to be involved in mental disorders in dialysis patients [16]. Most aluminum taken into the human body is excreted, with the remainder being stored in the brain, lungs, liver, and thyroid gland [16]. Aluminum is not known to have any useful function in the human body and is thought to have mostly harmful effects [16].

Aluminum chloride produces chromosomal aberrations in bone marrow of mice and is mutagenic to plant chromosomes [17]. Aluminum is also one of the few contaminants which accumulates in fish muscle [5].

Since aluminum is a common component of soils and sediments, it is more prone to gut-content bias of whole-body samples than most trace elements [18]. Other sources of aluminum include treated drinking water, baking soda, and food additives [15].

Aluminum in water and sediments is much more toxic to fish when mobilized by low pH [19]. This may be a significant factor in urban rivers having pockets of low pH in areas of industrial discharges or chlorine leaks [1]. Low levels (0.10 to 0.15 mg/L) of monomeric aluminum in water can be toxic to striped bass larvae at pH levels of 6.9 to 7.3 [20] [21].

The latest EPA water quality criteria for aluminum states that when pH is between 6.5 and 9.0, aluminum should not exceed 87 ug/L more than once every three years [19][22], so EPA considers low levels of aluminum to be potentially toxic.

CMFO RESULTS: ALUMINUM

All results reported are in dry weight unless stated otherwise.

Aluminum was detected in sediments at the six sites that were sampled for sediments. All sediment samples contained aluminum. The concentrations ranged from 3,220 ppm to 16,000 ppm. Sediments collected at the Clarence Cannon NWR 330 miles upstream on the Mississippi River had a high of 50,700 ppm.

Aluminum was detected in fish at two of the three sites where fish were captured. Aluminum was in eleven of the thirteen fish samples. The concentrations ranged from nondetect to 234 ppm. Fish were sampled at four NWR's and the NFH located in Missouri. The highest level was 573 ppm at Swan Lake NWR.

There is not sufficient data in the literature to make comparisons of sediment or whole body fish concentrations of aluminum.

Arsenic

(As, CAS Number 7440-38-2)

The following is taken from the Contaminant Encyclopedia [8]:

Arsenic is an element which has long been a concern to man because small amounts can be toxic to humans [23]. Arsenic exhibits both metallic and non-metallic properties [10].

Arsenic is found widely in nature and most abundantly in sulfide ores [24]. Arsenopyrite (FeAsS) is the most abundant one [24]. Arsenic compounds in nature may be organic or inorganic but occur mostly as arsenides and arsenopyrites [10]. Four arsenic species common in natural waters are arsenate (+5), arsenite (+3), methanearsonic acid and dimethylarsinic acid [10]. The chemical and toxicological properties of the forms appear to be quite different, so some recommend that the toxicities of these forms should be treated separately [10]. Trivalent inorganic arsenicals are more toxic to mammals and aquatic species than the pentavalent forms [10]. Arsenicals are used widely in industry and are a constituent of herbicides used in forest management and agriculture [22] [25].

Arsenic is a toxic pollutant designated pursuant to section 307(a)(1) of the Clean Water Act and is subject to effluent limitations [24]. In addition to its notoriety for toxicity in food and water, arsenic, pursuant to section 112 of the Clean Air Act, has been designated as a hazardous air pollutant [24]. Arsenic acts as a cumulative poison [26] and is listed by the Environmental Protection Agency as one of 129 priority pollutants [27]. Arsenic is also listed among the 25 hazardous substances thought to pose the most significant potential threat to human health at priority superfund sites [28]. Recent reviews indicate arsenic has been associated with carcinogenic, mutagenic, and teratogenic impacts [29] [30] [25]. Certain salts containing arsenic are probably causally related to cancer of the skin and liver [31].

Animals are generally less sensitive to arsenic than plants [32]. Among the most toxic arsenic compounds: arsine [26] and inorganic arsenicals [33]. In 1985, Hem updated a

summary of many basic water quality issues related to this element, including its sources and species, solubility controls, and its occurrence in natural water [23].

Plants take up arsenic from soil, groundwater, sewage sludge, biocides, fertilizers and air pollution [26]. Worldwide, perhaps 30% comes from weathering of soils [32]. Animals take up arsenic from drugs, biocides, industrial sources, contaminated water, and contaminated food [26]. Arsenic enters rivers from air pollution (fossil fuel combustion) and soil erosion as well as from pesticides and industrial sources. Significant amounts of arsenic are known to leach from municipal landfills [34]. Pesticides are an additional source of arsenic in water [5]. Arsenic is produced as a by-product of zinc, copper, and lead smelters--and possibly also produced through the large-scale burning of coal--poisons both livestock and humans [35].

Arsenic uses include [24]: alloying constituent, manufacture of certain types of glass; in metallurgy for hardening copper, lead alloys, to make gallium arsenide for dipoles & other electronic devices; doping agent in germanium & silicon solid state products; special solders; medicine, component of alloys; component of electrical devices, medication: to manufacture arsenical organic compounds for therapeutic use, As radioactive tracer in toxicology, Used as a catalyst in the manufacture of ethylene oxide, and in semiconductor devices. Arsenic is one of the metals used by ceramic artists; the others are lead, antimony, arsenic, barium, beryllium, boron, chromium, cobalt, cadmium, copper, and vanadium.

Arsenic as a free element (0-oxidation state) is rarely encountered in natural waters. Soluble inorganic arsenate (+5-oxidation state) predominates under normal conditions since it is thermodynamically more stable in water than arsenite (+3 oxidation state) [USEPA; Ambient Water Quality Criteria Doc: Arsenic p.A-1 (1980) EPA 440/5-80-021] [24].

Preliminary data suggests the potential for bioaccumulation or bioconcentration of arsenic is moderate for the following biota: mammals, birds, fish, mosses, lichens, and algae [26]. The potential is considered high to very high for mollusks, crustacea, lower animals, and higher plants [26]. The best potential mediums for biological monitoring appear to include animal hair, clams, algae, and higher plants [26]. Uptake of arsenic by phytoplankton can be significant [32]. Arsenic is one of the few metals which tends to concentrate in axial muscles of fish [36]. Arsenic is therefore of interest to those concerned with human health issues, since fillets are mostly muscle tissue.

When selenium is injected almost simultaneously with arsenic into test animals biliary excretion of both elements is enhanced seven to tenfold [24].

Rompala et al (1984) [5] report that arsenic's primary mode of toxicity to fish is its ability to react with proteins by enzyme inhibition. Toxicity may be related to the form of arsenic present. Laboratory studies have shown reduced survival and growth rates in immature bluegills in water containing 0.3 to 9.0 mg/l of arsenic; the tissue residues contained 1.3 and 5.0 ppm of arsenic [37].

CMFO RESULTS: ARSENIC

All results reported are in dry weight unless stated otherwise.

Arsenic was detected in sediments at the six sites that were sampled for sediments. All sediment samples contained arsenic. The concentrations ranged from 5.42 ppm to 20.0 ppm. Elevated levels of arsenic are indicated all sites sampled for sediments.

A background level of 1.1 ppm in sediments from Lake Michigan was reported by the International Joint Commission (IJC) (1988) [38]. EPA sediment classification criteria for arsenic lists < 3.0 ppm as nonpolluted (IJC 1982) [39]. Arsenic is classed as non-elevated at < 8.0 ppm in Illinois stream sediments [40]. Sediments collected at the Clarence Cannon NWR 330 miles upstream on the Mississippi River had a high of 40.3 ppm.

Arsenic was not detected in fish at any of the sites.

Barium

(Ba, CAS Number 7440-39-3)

The following is taken from the Contaminant Encyclopedia [8]:

A divalent alkaline earth metal [23], Barium, is a reactive metal which usually exists in nature as a salt, with the anion usually being a chloride, sulfate, or carbonate [42]. Barium is a malleable, yellow-white or silver-white, element which has a distinctive property of absorbing gases [24]. Barium is most often found in nature as barite (BaSO_4) and witherite (BaCO_3), both of which are highly insoluble salts [10]. However, many other salts of barium are soluble both in water and in acid and are poisonous [10]. Barium enters the body primarily through air and water; appreciable amounts are not contained in foods [10]. Its ions are thought to be rapidly precipitated or removed from solution by adsorption and sedimentation [22].

Barium salts are found in drilling mud and x-ray contrast mediums [42]. High concentrations have been found in oil field brines and oil field waters [23]. There is insufficient information on barium effects on mammals to say much about its mutagenic, carcinogenic, or reproductive effects [42].

The major uses of Barium are: a carrier for radium; alloys of barium with aluminum or magnesium are used as getters in electronic tubes; emissions from [21] barium contribute to fission products of uranium rods. [42]; emissions from barium are used as standards in gamma-spectrometry [42]; deoxidizer for copper; fray's metal; lubricant for anode rotors in x-ray tubes; spark-plug alloys; used in paints, soap, paper and rubber, and in manufacturing of ceramics and glass; used as a component in various proprietary nodularizing and deoxidizing alloys [17]; used extensively in manufacture of alloys for such products as

nickel-barium parts used in ignition equipment for automobiles and in manufacture of lithopone, glass, ceramics, and television picture tubes; as a loader for paper, soap, rubber, and linoleum; in radio industry for cleaning up last traces of gas in vacuum tubes [17]; as heat stabilizer for plastics; the largest end use of barium is as a "getter" to remove the last traces of gases from vacuum and television picture tubes; also used to improve performance of lead alloy grids of acid batteries; as a component of grey and ductile irons, and in the manufacture of steel, copper and other metals [24].

Barium is emitted into the atmosphere mainly by the industrial processes involved in the mining, refining, and production of barium and barium based chemicals and as a result of combustion of coal and oil [24].

CMFO RESULTS: BARIUM

All results reported are in dry weight unless stated otherwise.

Barium was detected in sediments at the six sites that were sampled for sediments. All sediment samples contained barium. The concentrations ranged from 50.7 ppm to 796 ppm. Sediments collected at the Clarence Cannon NWR 330 miles upstream on the Mississippi River had a high of 991 ppm.

Barium was detected in fish at all three of the sites where fish were captured. Barium was in all thirteen of the fish samples. The concentrations ranged from 4.35 to 42.5 ppm. Fish were sampled at four NWR's and the NFH located in Missouri. The highest level was 72 ppm at Clarence Cannon NWR.

There is not sufficient data in the literature to make comparisons of sediment or whole body fish concentrations of barium.

Beryllium

(Be, CAS Number 7440-441-7)

The following is taken from the Contaminant Encyclopedia [8]:

Beryllium is a chemical element, one of the alkaline-earth metals in Group IIA of the periodic table. Its atomic number is 4 and its atomic weight is 9.0122. A steel-gray metal, its properties are similar to those of aluminum and magnesium, except that its melting point, about 1,278 deg C, is high for a light metal. Chemically, beryllium differs markedly from the other alkaline-earth metals in that it forms compounds that are more covalent than ionic. Beryllium is a rare element: its concentration in the Earth's crust is approximately 6 ppm, and no rich deposits of it exist. It is produced from the mineral beryl. Beryllium and its compounds are extremely toxic. Inhalation of dust particles or vapors containing beryllium may cause berylliosis, an inflammation of the lungs [43].

Beryllium is listed by the Environmental Protection Agency as one of 129 priority pollutants [27], and is considered one of the 14 most noxious heavy metals [26]. Beryllium is also listed among the 25 hazardous substances thought to pose the most significant potential threat to human health at priority superfund sites [28]. Beryllium has been shown to be a carcinogen in rats and rabbits, to be teratogenic in a snail, and to cause developmental problems in salamanders [44] [30]. All beryllium compounds are potentially harmful or toxic [26]. Human impacts of beryllium include berylliosis, a severe lung inflammation caused by occupational exposure [16].

Beryllium can enter waters in effluents from certain metallurgical plants, but the inhalation of beryllium-containing fumes and dust originating from processing and fabrication operations poses the most serious health hazard to humans [22]. In the absence of a special source, river waters usually have very low or non-detectable concentrations of beryllium [23].

The addition of traces of beryllium to alloys can greatly increase their corrosion resistance. But the cost of beryllium, which is about 200 times that of aluminum, restricts its applications to a few special ones, such as in computer components, gyroscopes, and space technology. Beryllium is important in nuclear-reactor technology because it is an excellent neutron reflector and moderator. For this reason, and because of its strength and great resistance to heat, beryllium is employed as a cladding material for nuclear fuel elements. The most important beryllium compound is beryllium oxide, BeO. It is used as a base material in ceramics and in special types of glass; in fluorescent tubes; and in nuclear reactors [43].

Primary sources of beryllium to a river are typically atmospheric fallout from the burning of coal, soil erosion, industrial discharges, and sewage treatment plants [44]. Floodplain-located landfills containing discarded pieces of high technology equipment might also be a potential source. Plants take up beryllium from soil, groundwater, and air pollution [26]. Animals take up beryllium from contaminated water and food [26].

CMFO RESULTS: BERYLLIUM

All results reported are in dry weight unless stated otherwise.

Beryllium was detected in sediments at the six sites that were sampled for sediments. All sediment samples contained beryllium. The concentrations ranged from 0.917 ppm to 2.11 ppm. Sediments collected at the Clarence Cannon NWR 330 miles upstream on the Mississippi River had a high of 2.46 ppm.

Beryllium was not detected in fish at any of the sites.

There is not sufficient data in the literature to make comparisons of sediment or whole body fish concentrations of beryllium.

Boron

(B, CAS Number -Boron oxide- 1303-86-2)

The following is taken from the Contaminant Encyclopedia [8]:

Boron is a metalloid chemical element with properties intermediate between those of carbon and aluminum [45]. Boron is relatively rare, constituting only 3 ppm of the Earth's crust and is most commonly found in the minerals borax, and rasorite, or kernite [45]. Amorphous boron is an extremely hard, blackish-brown powder [45]. Boron does not occur in nature in its elemental state but instead is found as sodium or calcium borate salt [10]. Boron has three valence electrons and forms covalent compounds almost exclusively [45].

Boron hazards to fish and wildlife are summarized in Eisler's excellent 1990 synoptic review [46].

Boron is essential for plant growth, but apparently is not required by animals [22]. Boron is important in the calcium cycle of plants and borax or boric acid is often added to boron-poor soils as a fertilizer [45]. However, large amounts of boron in irrigation water can be harmful or toxic to plants [23]. Pecan, cherry, citrus, pear, grape, and many other trees are especially sensitive to boron [23]. Elevated concentrations of boron in aquatic plants, such as plants in areas associated with irrigation drainwater, can adversely impact duckling development [47].

Boron is not thought to be especially toxic to humans; borane is the most toxic compound [26].

Boron salts have a variety of uses, including fire retardants, leather tanning, and high-energy rocket fuels [10]. In addition, sodium borohydride is used by the pulp and paper industry in

the production of the whitening agent in sodium dithionite, and borax has long been used in detergents [48]. Elemental boron is frequently used for neutron absorption in nuclear reactors [10].

Plants take up boron from soil, groundwater, biocides, and air pollution [26]. Animals take up boron from industrial sources, contaminated water, and contaminated food [26]. At certain temperatures, boron behaves as a semiconductor, and it is often added to germanium and silicon to increase their electrical conductivity [45]. Small additions of boron to steel appreciably increase the hardness of the alloy. Boron is also used in the production of pure, strong metals to remove the oxygen and nitrogen dissolved in the metal or chemically bound to it, and it is used to absorb fast neutrons in nuclear reactors [45].

CMFO RESULTS: Boron

All results reported are in dry weight unless stated otherwise.

Boron was detected in sediments at the six sites that were sampled for sediments. All sediment samples contained boron. The concentrations ranged from 1.37 ppm to 93.7 ppm. Sediments collected at the Clarence Cannon NWR 330 miles upstream on the Mississippi River had a high of 20.9 ppm.

Boron was detected in one fish at one of the sites where fish were captured. The concentration was 1.37 ppm.

There is not sufficient data in the literature to make comparisons of sediment or whole body fish concentrations of boron.

Cadmium

(Cd, CAS Number 7440-43-9)

The following is taken from the Contaminant Encyclopedia [8]:

The chemical element cadmium is a relatively rare, soft, silver-white, transition element metal closely related to ZINC [49]. Its place in the periodic table is below zinc and above mercury, and it has many properties in common with these elements [49].

Cadmium hazards to fish and wildlife are summarized in Eisler's excellent 1985 synoptic review [50].

Cadmium is very toxic to a variety of species of fish and wildlife. Cadmium causes behavior, growth, and physiological problems in aquatic life at sublethal concentrations [5]. Cadmium tends to bioaccumulate in fish [5], clams [51] [52], and algae [52], especially in species living in close proximity to sediments contaminated by cadmium [52]. Cadmium ions are extremely poisonous; their action is similar to those of mercury [49].

Cadmium acts as a cumulative poison [26] and is listed by the Environmental Protection Agency as one of 129 priority pollutants [27]. Cadmium is also listed among the 25 hazardous substances thought to pose the most significant potential threat to human health at priority superfund sites [28]. All cadmium compounds are potentially harmful or toxic [26].

Cadmium is used in metal plating and in batteries. When it is smelted, it vaporizes into the atmosphere, and heavy concentrations can cause kidney and bone-marrow diseases and emphysema [35].

Cadmium is also a suspected carcinogen [17] [30] and has been shown to cause birth defects in mammals [17]. Mammals and birds consuming cadmium-contaminated food have experienced lowered sperm counts, kidney damage, increased mortality of young, elevated blood, sugar, and anemia [5].

Increased synthesis of metallothionein in response to mercury exposure may help animals acquire a somewhat increased tolerance of this metal [53].

A study of highway runoff indicated slight reductions of cadmium in water after it had run through a sedimentation pond and slightly more reduction after going from the detention pond through a wetland [54].

Cadmium forms only bivalent compounds, which do, however, form coordination compounds with other ions and molecules [49].

Plants take up cadmium from soil, groundwater, sewage sludge, biocides, and air pollution [26]. Animals take up cadmium from drugs, biocides, industrial sources, contaminated water, and contaminated food [26].

Air pollution sources of cadmium include smelters, incinerators, oil furnaces, and coal combustion. Metal platers, scrap yards, batteries, television tubes, solar cells, fungicides, and various industrial discharges constitute additional sources [5]. In some localities, significant amounts of cadmium are also present in sewage sludges [17] [55] and in leachates from municipal landfills [34] [56].

The following paragraph is quoted from reference [49]:

Cadmium compounds (the metal does not occur naturally in the free state) are almost always found together with zinc compounds, so that the two metals are always mined together. About 75% of all cadmium produced is used for cadmium plating of easily corroded metals such as iron and steel. Because of its low melting point, cadmium is used in special alloys such as aluminum solder (40% cadmium, 50% lead, 10% tin); Wood's metal (50% bismuth, 25% lead, 15% cadmium, 10% tin), which has a melting point of 70 deg C; and related alloys that are used, for example, in sprinkler installations and other fire-protection systems. Cadmium is also used to absorb neutrons in the control rods and shielding of nuclear reactors, and in the manufacture of artists' pigments, automobile enamels, vinyl plastics, and phosphors for color television tubes. Nickel-cadmium rechargeable batteries are more expensive than the usual lead storage batteries but, they have the advantage that they can be hermetically sealed, so that if they are overcharged, no gas evolution occurs. Therefore they can be used in such portable devices as flashlights, radios, hearing aids, and hand tools.

Preliminary data suggests the potential for bioaccumulation or bioconcentration of cadmium is high for the following biota: mammals, birds, fish, mosses, lichens, algae, mollusks, crustacea, lower animals, and higher plants [26]. The best potential mediums for biological monitoring appear to include animal hair, clams, algae, mosses, lichens, and higher plants [26]. Earthworms concentrate this metallic element relative to soil concentrations, which is one potential hazard of birds feeding on sewage sludge amended soils [57]. Concentrations of cadmium as high as 100 ppm (dry weight, a hazardous level for wildlife that eat worms) were detected in earthworms from soil containing only 2 ppm cadmium [57]. Irwin found mosquitofish to be acceptable for gradient monitoring of cadmium [1].

CMFO RESULTS: CADMIUM

All results reported are in dry weight unless stated otherwise.

Cadmium was detected in sediments at three sites that were sampled for sediments. Three sediment samples contained cadmium. The concentrations ranged from non-detect to 1.17 ppm. Elevated levels of cadmium are indicated at three sites sampled for sediments.

A background level of 0.6 ppm in sediments from Lake Michigan was reported by the International Joint Commission (IJC) (1988) [38]. EPA sediment classification criteria for cadmium lists <3.0 ppm as nonpolluted (IJC 1982) [39]. Cadmium is classed as non-elevated at <0.5 ppm in Illinois stream sediments [40]. Sediments collected at the Clarence Cannon NWR 330 miles upstream on the Mississippi River had a high of 2.96 ppm.

Cadmium was detected in five fish at one of the sites where fish were captured. The concentrations ranged from 0.198 ppm to 0.394 ppm. The 0.394 ppm dry weight sample converted to wet weight is 0.081 ppm. This is an elevated level.

The geometric mean for whole fish samples from 109 stations nationwide in the National Contaminant Biomonitoring Program was 0.03 ppm wet weight [2].

Chromium

(Cr, CAS Number 7440-47-3)

The following is taken from the Contaminant Encyclopedia [8]:

Chromium is a metallic element which is listed by the Environmental Protection Agency as one of 129 priority pollutants [27]. Chromium is considered one of the 14 most noxious heavy metals [26]. Chromium is also listed among the 25 hazardous substances thought to pose the most significant potential threat to human health at priority superfund sites [28].

Chromium does not occur free in nature; in bound form it makes up 0.1-0.3 parts per million of the Earth's crust [58]. Some salts of chromium are carcinogenic [30] and humans exposed to chromium fumes have an increased risk for lung cancer [16]. Specific chromium compounds are quite toxic but the element itself has moderate to low toxicity [26] and poisoning from excess chromium is rare in humans [16].

Although the most important valences of chromium are 3 and 6, chromium with valences of 1, 2, 4, and 5 has also been shown to exist in a number of compounds [58]. Chromium VI is listed by EPA as a class A human carcinogen. Chromium compounds with a valence of 6 are called chromates; most have a yellow color and all are toxic [58].

The toxicity of chromium is highly related to speciation [33]. Small amounts of trivalent chromium are considered essential in animals and man [24]. However, chromium deficiency is unknown, and too much chromium can be harmful to humans [16].

The greatest chromium toxicity risk to plants is posed in acidic sandy soil with low organic content [24]. In plants, chromium interferes with uptake translocation, and accumulation by plant tops of calcium, potassium, magnesium, phosphorus, boron, copper and aggravates iron deficiency chlorosis by interfering with iron metabolism [24].

Trivalent chromium is the most common form in rocks of the earth's crust, but both trivalent and hexavalent chromium occur as dissolved chromium [23]. Both forms (especially hexavalent) are significant from the standpoint of potential impacts to fish and wildlife [59] [5]. Since the valence states are subject to change, we analyze tissues for total chromium. During the laboratory digestion of tissue samples, most chromium is changed to the trivalent form.

Most of the chromium in surface waters may be present in particulate form as sediment; some of the particulate chromium would remain as suspended matter and ultimately be deposited in sediments [24]. Freshwater fish can regulate chromium over a wide range of ambient concentrations [53]. Some have even stated that freshwater fish seem to be relatively tolerant of chromium, although some aquatic invertebrates are very sensitive [22] [10].

Highway runoff routed through a detention pond and then a cypress wetland resulted in much higher sediment levels in the detention pond than in the wetland [54]. However, the same study indicated that chromium deposits in a freshwater wetland were not always nearest the inlet, possibly indicating that chromium travels farther before settling or adsorbing than some other metals [54].

Chromium compounds with a valence of 6 are called chromates; most have a yellow color and all are toxic. When absorbed into the body they severely irritate the gastrointestinal tract, leading to circulatory shock and renal damage. Chromate yellow, one of the most important yellow pigments, is highly toxic because it contains both chromium and lead. Chromates are used as anti-corrodents in water-cooling systems. Unfortunately, because they are toxic, their runoff has severe effects on river flora. It is economically and ecologically wise to remove chromates before waste water is released [58].

Chromated copper arsenate (CCA), wood preservative chromated copper arsenate (60%) soluble concentrate is 9.9% arsenic pentoxide, 39.3% chromic acid, and 10.8% cupric oxide [24]. CCA Type C Wood Preservative (60%), solution-ready to use, is 20.1% arsenic pentoxide, 28.5% chromic acid, 11.4% cupric oxide [60].

Although copper arsenate was a restricted use pesticide which at one time was voluntarily cancelled [61], CCA is apparently still used as a wood preservative. It is the treatment of

choice on wood used for decks and results in a greenish-gray wood. Concerns have been raised related to human health and possible dermal exposure, but we have not yet found information in the literature on fish and wildlife impacts of this compound. The wood preserving industry has stated there is little hazard to humans as long as wood preserved with CCA is not burned or used as a cutting board.

One of the biggest concerns related to CCA treated wood in the aquatic environment is leaching of copper. An alternative to the use of cheap wood treated with CCA is the use of oak or black locust, which may last as long in water without being treated with CCA.

Plants take up chromium from soil, groundwater, surface water, sewage sludge, fertilizers and air pollution [26]. Animals take up chromium from industrial sources, contaminated water, and contaminated food [26]. Known sources of chromium include metal platers and a wide variety of chemical, photography, metal plating, scrap metal, machine shop, power plant, and industrial facilities [59] [5]. Chromium is also present in the leachate of some municipal landfills [56].

CMFO RESULTS: CHROMIUM

All results reported are in dry weight unless stated otherwise.

Chromium was detected in sediments at the six sites that were sampled for sediments. All sediment samples contained chromium. The concentrations ranged from 25.5 ppm to 80.1 ppm. Sediments collected at the Clarence Cannon NWR 330 miles upstream on the Mississippi River had a high of 69.7 ppm. Elevated levels of chromium were detected at all sites sampled for sediments.

A background level of 37.1 ppm in sediments from Lake Michigan was reported by the International Joint Commission (IJC) (1988) [38]. EPA sediment classification criteria for chromium lists <25.0 ppm as nonpolluted (IJC 1982) [39] [39]. Chromium is classed as non-elevated at <16.0 ppm in Illinois stream sediments [40].

Chromium was detected in fish at all three of the sites where fish were captured. Chromium was in all thirteen of the fish samples. The concentrations ranged from 0.543 to 1.24 ppm. Elevated levels of chromium were detected at two of the three sites where fish were collected.

Chromium levels above 0.8 ppm in fish and wildlife tissues are considered definitely elevated by Irwin 1988 [62] [63] [64]. Fish were sampled at four NWR's and the NFH located in Missouri. The highest level was 5.4 ppm at Swan Lake NWR.

Cobalt

(Co, CAS Number 7440-48-4)

The following is taken from the Contaminant Encyclopedia [8]:

The chemical element cobalt is a hard silver metal with a bluish sheen having chemical properties like those of iron and nickel [65]. Cobalt occurs naturally in the earth's crust and is essential in plant and animal nutrition, especially for ruminant animals [23]. A deficiency of vitamin B-12, which is a cobalt compound, can cause pernicious anemia [65].

Cobalt usually occurs in divalent and trivalent oxidation states [23]. The most common valence of cobalt is +2; trivalent cobalt salts are usually strong oxidizing agents, and a valence of +4 occurs in rare instances [65].

Plants take up cobalt from soil, groundwater, and air pollution [26]. Cobalt is 0.001% to 0.002% of the Earth's crust [65]. Never found in pure form, cobalt is usually bonded to arsenic and sulfur [65]. Animals take up cobalt from industrial sources, contaminated water, and contaminated food [26]. Cobalt is a relatively expensive metal used in the manufacture of valuable alloys [65]. Co-59 is the only naturally-occurring cobalt isotope and is often added to hydrogen bombs [65]. Co-60 is used in cancer research and as a source of X rays [65].

CMFO RESULTS: COBALT

All results reported are in dry weight unless stated otherwise.

Cobalt was detected in sediments at the six sites that were sampled for sediments. All sediment samples contained cobalt. The concentrations ranged from 5.9 ppm to 28.4 ppm.

There is not sufficient data in the literature to make comparisons of sediment or whole body fish concentrations of cobalt.

Copper

(Cu, CAS Number 7440-50-8)

The following is taken from the Contaminant Encyclopedia [8]:

The chemical element copper is a reddish metal [66]. Copper is widely distributed in nature in the elemental state, in sulfides, arsenites, chlorides, and carbonates; the element is only superficially oxidized in air, sometimes giving a green coating of hydroxy carbonate and hydroxy sulfate [24]. Copper exhibits oxidation states of +2 (the most common, forming Cu(II) compounds), and +1 (Cu(I), stable only in aqueous solution if part of a stable complex ion); a few compounds of copper(III) are also known [66]. Copper is listed by the Environmental Protection Agency as one of 129 priority pollutants [27]. Elevated water

concentrations are quite toxic to many aquatic species [24]. A water's alkalinity directly affects the toxicity of copper to aquatic life, which generally is augmented at lower alkalinities [10]. As most adult fish are able to tolerate relatively high concentrations of copper for short periods of time, the critical effect of copper is its greater toxicity to younger fish [22].

Copper is a toxic pollutant designated pursuant to section 307(a)(1) of the Clean Water Act and is subject to effluent limitations [24]. However, minute amounts of copper in the diet are needed for human, plant, and animal enzymes [16] [53] [66], and copper poisoning or deficiency problems are rare in humans [16]. Copper usually occurs as part of the oxidizing enzymes such as ascorbic acid oxidase, tyrosinase, lactase, and monoamine oxidase [66]. These enzymes, which are high-molecular-weight proteins containing 0.05%-0.35% of Cu, play an important part in living oxidation and reduction reactions, in which the copper undergoes cyclic changes between Cu(I) and Cu(II) oxidation states [66].

Copper is tightly bound to ligand sites, containing oxygen, sulfur, or nitrogen atoms on the protein [66]. Many higher organisms can conserve copper when it is deficient and excrete it when an excess amount enters the body [53]. Freshwater fish can regulate copper over a wide range of ambient concentrations [53].

Absorption of dietary copper in higher animals is apparently regulated in part by metal thioneins, low molecular weight proteins containing high levels of cysteine [53]. Copper is an important trace element in plant metabolism [53].

Copper can be toxic in large quantities, especially to lower organisms such as bacilli, fungi, and algae [66].

Some researchers believe that negative effects of copper on fish are more likely the result of toxicity of high concentrations in water than toxicity from intake of prey containing copper [67]. However, in all animals studied, continued ingestion of copper in excess of dietary requirements led to some accumulation in tissues, particularly the liver and kidneys [53]. Excess copper accumulation can lead to copper toxicosis and cell damage [53].

Increased synthesis of metallothionein in response to copper exposure may help animals acquire a somewhat increased tolerance of this metal [53]. Fish living or foraging in contaminated sediments may accumulate it directly from the sediments [52].

Although an essential dietary element for some plants and animals, high concentrations of copper in water can be toxic to fish [67] [26]. Elevated concentrations of copper in water are particularly toxic to many species of algae, crustaceans, annelids, cyprinids, and salmonids [53].

In water, copper acts synergistically with other common urban contaminants such as ammonia, cadmium, mercury, and zinc to produce an increased toxic effect on fish [68] [69].

Sublethal concentrations adversely affect minnow fry survival and growth [5]. In 1985, Hem updated a summary of many basic water quality issues related to this element, including its sources and species, solubility controls, and its occurrence in natural water [23].

Elemental copper supplied from a mixed copper ethanolamine complex (Cutrine-plus algicide liquid concentrate, made by Applied Biochemists Inc.) is a registered herbicide/algicide for use in controlling Chara, Nitella, and hydrilla [70]. Copper sulfate is also used to control Chara and pondweeds [70].

Highway runoff routed through a detention pond and then a cypress wetland resulted in much higher sediment levels of copper in the detention pond than in the wetland [54]. The same study indicated that copper deposits near the outlet of a freshwater wetland were lower than those in the middle [54].

Copper was the first metal used by humans and is second only to iron in its utility through the ages. Copper mixes well with many elements, and more than 1,000 different alloys have been formed, several of which are technologically significant. The presence of the other element or elements can modify the hot or cold machining properties, tensile strength, corrosion fatigue, and wear resistance of the copper; it is also possible to create alloys of pleasing colors.

The electrical industry is a major consumer of copper. The metal is used for the windings of generators and for conveying electrical power. Its resistance to chemical attack and its high thermal conductivity make copper a useful metal for condensers in chemical plants and for car radiators. Copper tubing is widely employed in plumbing, and finely divided copper is used as an industrial catalyst in the oxidation of methanol to formaldehyde. Copper compounds, such as Fehling solution, are used in analytical tests for sugars. Copper(II) sulfate has many industrial applications, including the preparation of Bordeaux mixture (a fungicide) and the manufacture of other copper compounds. It is also used in electroplating solutions, in textile dyeing, and as a timber preservative. Probably the earliest use of copper as a fungicide was in the form of copper sulfate solution employed as a seed dressing to destroy cereal disease, such as bunt.

New materials are increasingly replacing copper: plastic for pipe and tubing, glass fiber for wire, lightweight aluminum for automobile parts.

Plants take up copper from soil, groundwater, sewage sludge, biocides, fertilizers and air pollution [26]. Animals take up copper from industrial sources, contaminated water, and contaminated food [26]. Copper is one of the most common contaminants associated with urban runoff, and specific sources include soil erosion, corrosion of pipes and tubes, industrial discharges, and sewage treatment plant discharges [67]. Copper is also present in the leachate of some municipal landfills [56] and in sludges generated by sewage treatment plants [55]. Water particularly water that is acidic, low in hardness and alkalinity, and consequently corrosive to piping, may leach copper from drinking water pipes [24].

CMFO RESULTS: COPPER

All results reported are in dry weight unless stated otherwise.

Copper was detected in sediments at the six sites that were sampled for sediments. All sediment samples contained copper. The concentrations ranged from 10.5 ppm to 48.0 ppm. Sediments collected at the Clarence Cannon NWR 330 miles upstream on the Mississippi River had a high of 83.6 ppm. Elevated levels of copper were detected at all sites sampled for sediments.

A background level of 21.0 ppm in sediments from Lake Michigan was reported by the International Joint Commission (IJC) (1988) [38]. EPA sediment classification criteria for copper lists 25.0 ppm as nonpolluted (IJC 1982) [39]. Arsenic is classed as non-elevated at <38.0 ppm in Illinois stream sediments [40].

Copper was detected in fish at all three of the sites where fish were captured. Copper was in all thirteen of the fish samples. The concentrations ranged from 2.32 to 11.6 ppm. Elevated levels of copper were detected at all of the three sites where fish were collected. Elevated levels were detected in all but one of the fish samples.

Fish were sampled at four NWR's and the NFH located in Missouri. The highest level was 60.1 ppm at Clarence Cannon NWR. The geometric mean for whole fish samples from 109 stations nationwide in the National Contaminant Biomonitoring Program was 0.65 ppm wet weight [2].

Iron (Fe)

The following is taken from the Contaminant Encyclopedia [8]:

Iron is a silvery white, solid, transition element metal with an atomic number of 26 and an atomic weight is 55.847 [71]. Iron is the fourth most abundant element in the earth's crust and is an essential trace element required by both plants and animals [22]. Iron has four natural isotopes; the most abundant has a mass of 56 (91.66%); the latter occurs with isotopes having masses of 54 (5.82%), 57 (2.19%), and 58 (0.33%) [71].

In localities where it is elevated, iron is an important freshwater quality ion which contributes to water "hardness" [22]. Iron concentrations in excess of 0.3 mg/l can cause stains on laundry [71].

In 1985, Hem updated a summary of many basic water quality issues related to iron, including its sources and species, the role of bacteria in iron precipitation, reaction rates, solubility controls, and its occurrence in natural water [23]. In aqueous solutions the

chemistry of iron in the +2 or the +3 oxidation state is complex; many oxidizing and reducing agents are capable of interconverting its various compounds [71].

The primary sources of iron in rivers include soil erosion, urban runoff, and industrial discharges. Iron is also present in the leachate of some municipal landfills [56].

In some waters, iron may be a limiting factor in growth of algae and plants [22]. Iron plays an essential role in oxygen transport in all vertebrates and some invertebrates [22]. Iron is the central atom in heme, the oxygen-carrying portion of hemoglobin found in blood [71].

Body burden issues are not well understood. Little is known about the effects of predators consuming fish carrying excess iron. Iron tends to accumulate in the brains of rats as they age and may play a role in oxidative damage to brain tissues [73].

CMFO RESULTS: IRON

All results reported are in dry weight unless stated otherwise.

Iron was detected in sediments at the six sites that were sampled for sediments. All sediment samples contained iron. The concentrations ranged from 20,300 ppm to 44,900 ppm. Sediments collected at the Clarence Cannon NWR 330 miles upstream on the Mississippi River had a high of 124,000 ppm. Elevated levels of iron were detected at all sites sampled for sediments.

A background level of 22,278 ppm in sediments from Lake Michigan was reported by the International Joint Commission (IJC) (1988) [38]. EPA sediment classification criteria for iron lists <17,000 ppm as nonpolluted (IJC 1982) [39]. Arsenic is classed as non-elevated at <18,000 ppm in Illinois stream sediments [40].

Iron was detected in fish at all three of the sites where fish were captured. Iron was in all thirteen of the fish samples. The concentrations ranged from 112 to 411 ppm.

Fish were sampled at four NWR's and the NFH located in Missouri. The highest level was 1360 ppm at Squaw Creek NWR.

There is not sufficient data in the literature to make comparisons of whole body fish concentrations of iron.

Lead

(Pb, CAS Number 7439-92-1)

Lead is a soft, gray, acid-soluble metal ranked as the 36th element in order of abundance [36] and is a major constituent of more than 200 identified minerals. Although metallic lead and lead minerals are not considered water soluble, some industrially produced lead

compounds are. Lead solubility is inversely related to pH. Inorganic lead, in the +2 valence state, is more stable than organic lead compounds in the +4 valence state [5].

Lead is very toxic to aquatic organisms, with fish being the most sensitive. Water concentrations of 0.3 mg Pb/l killed fish but had little effect on invertebrates [74] [5].

Survival of fish is adversely affected because lead causes increased mucus formation, interference with gaseous exchanges and changes in the physical properties of epidermal mucus [36]. Effects of high lead concentrations in fish include delayed embryonic development, suppressed reproduction and inhibition of growth rate [5].

Normally, little or no lead is available to aquatic systems. However, lead has been demonstrated to be at high levels in areas of metal mining and metal smelting. Lead was found to be less available to aquatic biota in soft water systems. Much evidence suggests that often lead is not bioconcentrated [75] [76].

The following is taken from the Contaminant Encyclopedia [8]:

Lead is a heavy metal which is very toxic to aquatic organisms, especially fish [5]. It tends to bioaccumulate in mussels and clams [51] [52]. Benthic fish may accumulate lead directly from the sediments [52]. Some salts of this element are carcinogenic [30]. Lead is listed by EPA as a class B2 carcinogen, sufficient evidence to be classed as an animal carcinogen. All lead compounds are potentially harmful or toxic, especially tetraethyl lead [26].

Lead functions as a cumulative poison [26] and is listed by the Environmental Protection Agency as one of 129 priority pollutants [27]. Lead is also listed among the 25 hazardous substances thought to pose the most significant potential threat to human health at priority superfund sites [28].

All measured effects of lead on living organisms are adverse, including those negatively affecting survival, growth, learning, reproduction, development, behavior, and metabolism [75]. Effects of sublethal concentrations of lead include increased mucous formation, delayed embryonic development, suppressed reproduction, inhibition of growth, and fin erosion [5]. In vertebrates, sublethal lead poisoning is characterized by neurological problems (including blockage of acetylcholine release), kidney disfunction, enzyme inhibition, and anemia [53].

Lead shot poisoning of waterfowl has been widely publicized but can also occur in bald eagles and other species of fish and wildlife [36]. In birds, lead has also been implicated in decreases in eggshell thickness, growth, ovulation, and sperm formation [5].

Elevated concentrations of lead in water are particularly toxic to many species of algae [53]. Synergistic effects of lead and cadmium and additive effects of lead, mercury, copper, zinc, cadmium, and mercury have been documented for aquatic biota [36]. The many negative

effects of lead on physiology and heme formation [75] increase lead's potential for synergistic or additive effects with other contaminants and with low oxygen stress.

Airborne lead from automobile and industrial emissions is absorbed into the body through the lungs [35]. At present the average blood-lead levels in an urban adult are estimated at 75 to 100 times the natural level [35]. Lead poisoning is particularly dangerous in young children (who may ingest lead by eating lead-containing chips of paint); it may result in anorexia and--in severe cases--permanent brain damage [35].

Plants take up lead from soil, groundwater, sewage sludge, biocides, and air pollution [26]. Animals take up lead from industrial sources, contaminated water, licking or preening fur or feathers, lead shot, and contaminated food [26].

Typical sources of lead in rivers include atmospheric fallout from motor vehicle and smelter emissions as well as sewage sludge, batteries, pipes, lead shot, glazes, paints, and alloys. Significant amounts of lead are also known to leach from municipal landfills [34] [56]. Lead is also a common contaminant in used motor oil [77] and in sludges generated by sewage treatment plants [55]. Airborne lead is deposited on vegetation and wildlife living near highways, and some urban zoos have experienced lead poisoning [78]. The national average concentration for lead in U.S. soils is 10 mg/kg [79], but much higher concentrations are common near busy highways [80]. Sediments can act as a sink for lead and a continuing source of lead after the original source has subsided [75]. In some areas, lead shot also ends up in sediment, and may be ingested by bottom feeding biota. Lead removals by wetlands and detention ponds receiving highway runoff is high [54].

CMFO RESULTS: LEAD

All results reported are in dry weight unless stated otherwise.

Lead was detected in sediments at the six sites that were sampled for sediments. All sediment samples contained lead. The concentrations ranged from 1.28 ppm to 47.0 ppm. Sediments collected at the Clarence Cannon NWR 330 miles upstream on the Mississippi River had a high of 940 ppm. Elevated levels of lead were detected at all sites sampled for sediments.

A background level of 27.5 ppm in sediments from Lake Michigan was reported by the International Joint Commission (IJC) (1988) [38]. EPA sediment classification criteria for lead lists <40.0 ppm as nonpolluted (IJC 1982) [39]. Lead is classed as non-elevated at <28.0 ppm in Illinois stream sediments [40].

Lead was detected in fish at two of the three sites where fish were captured. The concentrations ranged from 1.28 ppm to 5.12 ppm. The 5.12 ppm dry weight sample converted to wet weight is 1.664 ppm. This is an elevated level.

The geometric mean for whole fish samples from 109 stations nationwide in the National Contaminant Biomonitoring Program was 0.11 ppm wet weight [2].

Fish were sampled at four NWR's and the NFH located in Missouri. The highest level was 4.4 ppm dry weight at Mingo NWR.

Magnesium

(Mg, CAS Number -Magnesium oxide- 1309-48-4)

The following is taken from the Contaminant Encyclopedia [8]:

Magnesium is a silvery white metallic element which lies in group IIA of the periodic table, has an atomic number of 12, and has an atomic weight of 24.312 [81]. Magnesium is a divalent alkaline earth metal (a common component of the earth's crust) [23]. Along with calcium, magnesium is one of the two most common polyvalent metallic ions in freshwater and a major contributor to water "hardness" [22]. In 1985, Hem updated a summary of many basic water quality issues related to this element, including its sources and forms and its occurrence in natural water [23].

Magnesium has some useful physiological functions and small amounts of magnesium in the diet are necessary to control cell metabolism [16]. Magnesium cations (positively charged ions) play an important role in various biological processes. Like calcium, magnesium ions play major roles in humans in nerve conduction, muscle contraction, and bone formation [16]. Magnesium ions also play important roles in enzyme activation and protein metabolism [16]. Also like calcium, magnesium is often used as a dietary supplement in multi-mineral pills consumed by humans.

Little is known concerning whether or not highly elevated levels of magnesium in animal tissues might be harmful to the organism or fish and wildlife species which consume the organism. In humans, most magnesium is stored in bones and teeth. Excess magnesium intake in humans has led to heart damage and respiratory failure [16]. Magnesium is considered relatively nontoxic to humans since it becomes unpalatable before dangerous concentrations are reached [82] [10].

Magnesium is one of the most important metals in both plants and animals. The body of an average adult contains about 25 g (0.9 oz) of magnesium; however, the specific actions of magnesium in the human body are still unknown. Magnesium is known to be an activator of many enzyme systems and acts as a depressant of the central nervous system when it is injected intravenously. For this reason, magnesium and some of its compounds are used to control convulsions resulting from tetanus and childbirth. Magnesium is found in many foods, such as meats, cereals, vegetables, and milk. The average adult ingests about 300 mg (0.01 oz) of magnesium per day. Magnesium deficiency results in weakness, dizziness, and convulsions. The kidneys regulate the amount of magnesium in the body, and magnesium

overdose may result from kidney failure, hormonal disruption, or use of too much magnesium as a drug [81].

Finely divided magnesium burns in air with an intense white light, so the metal is used as the source of light in some flashbulbs, fireworks, and pyrotechnics. Magnesium is also used in incendiary bombs, in the production of titanium and zirconium, as a catalyst in some organic chemical reactions, and in the manufacture of copper and nickel alloys. In aeronautical design, the expensive metal zirconium is often the alloying additive, as it produces very strong materials. Because of their light weight, magnesium alloys are used as structural materials for the fuselages of airplanes, guided missiles, electronic equipment, portable tools, baseball catcher's masks, snowshoes, skis, boats, horseshoes, luggage, ladders, and racing cars.

Magnesium carbonate is a white powder that is used as a filler for paper, in cosmetics and fire-resistant and insulating materials, and for clarifying drinking water. When magnesium carbonate is boiled in water, magnesia alba is formed. Magnesia alba is used as an antacid and as a laxative. Magnesium sulfate is marketed as epsom salts, which are used as laxatives. Magnesium sulfate is used in medicine in the treatment of arthritis and burns and as a local analgesic. It is also used for tanning leather, dyeing textiles, and in ceramics, explosives, and match manufacture. Milk of magnesia is used as an antacid and as a laxative. A group of organic magnesium compounds, known as grignard reagents, are used in the synthesis of many organic compounds and in the production of silicones.

CMFO RESULTS: MAGNESIUM

All results reported are in dry weight unless stated otherwise.

Magnesium was detected in sediments at the six sites that were sampled for sediments. All sediment samples contained magnesium. The concentrations ranged from 285 ppm to 2300 ppm. Sediments collected at the Clarence Cannon NWR 330 miles upstream on the Mississippi River had a high of 10,800 ppm.

Magnesium was detected in fish at all three of the sites where fish were captured. Magnesium was in all thirteen of the fish samples. The concentrations ranged from 1000 to 1770 ppm. Fish collected at Clarence Cannon NWR had a high of 10,600 ppm.

There is not sufficient data in the literature to make comparisons of sediment or whole body fish concentrations of magnesium.

Manganese

(Mn, CAS Number 7439-96-5)

The following is taken from the Contaminant Encyclopedia [8]:

The chemical element manganese is a silver gray transition element metal with an atomic number of 25 and an atomic weight of 54.938 [83]. Manganese occurs in nature in various salts and oxides and it is used in various industrial and agricultural applications [22].

In localities where it is elevated, manganese is an important freshwater quality ion which contributes to water "hardness" [22]. In 1985, Hem updated a summary of many basic water quality issues related to manganese, including its sources and species, redox processes, and its occurrence in natural water [23].

Body burden issues are less well understood. Manganese is a required trace element for both plants and animals [22]. Beef cattle fed corn may require manganese supplements [22]. Fish have some ability to excrete excess manganese, but the precise significance of excess body burdens of manganese is unclear for most species of fish and wildlife. Manganese tends to accumulate in bone, skin, and scales [84].

Manganese is thought to present less of a toxicity problem in natural waters than many of the other contaminants typically analyzed in ICP scans [85]. Poisonings from excess levels have occurred in humans but are rare [5] [22].

The most frequently occurring valence of manganese is +2, but +4, +6, and +7 are also common, and +1, +3, and +5 are known [83].

Pure manganese is rarely used, as it is a moderately reactive and brittle metal [83]. However, manganese occurs naturally in surface waters from soil erosion. Other sources include air pollution deposition from power plants, sewage treatment plant effluents, and leachates from municipal landfills [56].

The Earth's crust contains 850 ppm manganese in chemically bonded form. By far the most important manganese mineral is pyrolusite, which consists largely of manganese dioxide [83]. About 95% of the world's annual production of manganese is used by the iron and steel industry [83]. In alloys, manganese increases the durability and corrosion resistance of iron and steel and makes steel more malleable when forged [83]. Manganese alloys are used in grinding machinery, wrecking equipment, caterpillar trucks, and mechanical pounding equipment used in heavy-duty construction [83].

CMFO RESULTS: MANGANESE

All results reported are in dry weight unless stated otherwise.

Manganese was detected in sediments at the six sites that were sampled for sediments. All sediment samples contained manganese. The concentrations ranged from 370 ppm to 2920 ppm. Sediments collected at the Clarence Cannon NWR 330 miles upstream on the Mississippi River had a high of 7,180 ppm.

Manganese was detected in fish at all three of the sites where fish were captured. Manganese was in all thirteen of the fish samples. The concentrations ranged from 6.19 to 79.9 ppm. Fish collected at Clarence Cannon NWR had a high of 164.0 ppm.

There is not sufficient data in the literature to make comparisons of sediment or whole body fish concentrations of manganese.

Mercury

(Hg, CAS Number -Hydragyrum- 7439-97-6)

The following is taken from the Contaminant Encyclopedia [8]:

Mercury is the only metallic element that is liquid at room temperatures, and its volatility tends to reduce its concentration in surface waters [23]. It is a cumulative poison [26] and is the heavy metal most toxic to fish [86]. Elevated concentrations of mercury in water are particularly toxic to many species of algae, crustaceans, and salmonids [53]. Mercury's use in pesticides has been restricted [61].

Mercury is listed by the Environmental Protection Agency as one of 129 priority pollutants [27]. Methyl and alkyl mercury compounds are two of the most toxic classes of mercury compounds [26]. Mercury deposits in the brain cause many disorders and sometimes dementia in humans [16]. Mercury deposits in human kidneys may lead to renal failure [16].

Mercury is one of the few metals which strongly bioconcentrates and biomagnifies; has only harmful effects with no useful physiological functions when present in fish and wildlife; is a carcinogen, mutagen, and teratogen; and is easily transformed from a less toxic inorganic form to a more toxic organic form in fish and wildlife tissues [86]. It is a metal whose use should be curtailed as much as possible to prevent impacts to fish and wildlife [86]. When exposed to mercury in both mediums, fish accumulate more mercury from sediments than from water [52]. Lower pH levels (indicating increased acidification) are correlated with increased mercury accumulation in fish [87].

Increased synthesis of metallothionein in response to mercury exposure may help animals acquire a somewhat increased tolerance of this metal [53].

Mercury in bottom sediments is resuspended during floods and carried further downstream. Such events have resulted in increased levels of mercury in fish, as noted in a previous Fish and Wildlife Service study in Montana [88]. Mercury is one of the few metals which accumulates in the axial muscles of fish, so fillet levels are typically closer to whole-body concentrations than for most other contaminants [84].

Mercury poisoning has occurred in the United States and in other countries. The most notorious episode, however, occurred in the 1950s at Minamata Bay in Japan, where mercury in the effluent from a plastics factory was ingested (in the form of methyl mercury, an organic compound) by fish and, eventually, by people in the fishing communities on the bay [35].

Plants take up mercury from soil, groundwater, sewage sludge, biocides, fertilizers, and air pollution [26]. Animals take up mercury from industrial sources, contaminated water, and contaminated food [26].

Sources of mercury include batteries, vapor discharge lamps, thermometers, older-style seals in sewage treatment plants, sewage treatment plant discharges, the chloralkali industry, paints, pesticide compounds, switches, valves, dental labs and offices, pharmaceuticals, scientific and analytical laboratories, soil erosion, and air pollution deposition from fossil fuel combustion and smelters [86]. Other uses include: barometers, hydrometers, pyrometers, mercury arc lamps, florescent lamps, catalysts, and gold extraction [89]. Leachates of municipal landfills contain mercury [56], possibly due to the disposal of items such as mercury batteries, thermometers, and electrical switches. Contact lens solutions containing thimerosal are an additional source of small amounts of mercury. Many sources of small amounts of mercury can have a cumulative impact on a small river, due to mercury's persistence.

About 10,000 U.S. tons of mercury are mined each year, half of which is lost into the environment [35].

CMFO RESULTS: Mercury

All results reported are in dry weight unless stated otherwise.

Mercury was detected in sediments at the six sites, except site four, that were sampled for sediments. The concentrations ranged from 0.027 ppm to 0.0896 ppm. Sediments collected at the Clarence Cannon NWR 330 miles upstream on the Mississippi River had a high of 0.205 ppm. Elevated levels of mercury were detected in thirteen of the sediment samples.

A background level of 0.03 ppm in sediments from Lake Michigan was reported by the International Joint Commission (IJC) (1988) [38]. Mercury is classed as non-elevated at <0.07 ppm in Illinois stream sediments [40].

Mercury was detected in fish at all three of the sites where fish were captured. Mercury was in all thirteen of the fish samples. The concentrations ranged from 0.0801 to 1.73 ppm. The 1.73 ppm sample converted to wet weight is 0.4671 ppm. Elevated levels of mercury were detected at all of the three sites where fish were collected. Elevated levels were detected in all but one of the fish samples.

Fish were sampled at four NWR's and the NFH located in Missouri. The highest level was 5.51 ppm at Mingo NWR. The geometric mean for whole fish samples from 109 stations nationwide in the National Contaminant Biomonitoring Program was 0.10 ppm wet weight [2].

Molybdenum

(Mo, CAS Number 7439-98-7)

The following is taken from the Contaminant Encyclopedia [8]:

Molybdenum is a silver-white metallic chemical element of the second transition series; its atomic number is 42 and its atomic weight is 95.94 [90]. The free element does not ordinarily occur in nature, but it is extracted from molybdenite, wulfenite, and powellite and is recovered as a by-product of copper and tungsten mining operations [90].

Molybdenum has a melting point of 2,617 deg C, a boiling point of 4,612 deg C, and a density of 10.22 g/cu cm [90]. It exhibits oxidation states of 0, +1, +2, +3, +4, +5, and +6 [90]. The metal is very hard but more ductile than the chemically similar element tungsten [90].

Molybdenum is a valuable alloying agent, contributing to the harden-ability and toughness of quenched and tempered steels. Almost all high-strength steels contain molybdenum in amounts from 0.25 to 8% by weight. Molybdenum is also used in the "hastelloys," which are nickel-based alloys with heat-resistant and corrosion-resistant properties [90].

Molybdenum wire is used for filaments for metal evaporation and as a filament, grid, and screen material for electronic tubes [90]. Other applications of the metal include use as electrodes for electrically heated glass furnaces [90]. Molybdenum sulfide is widely used as a high-temperature lubricant [90].

Molybdenum is considered an essential micronutrient and is present in all life form tissues [91]. Too little Mo can be a problem for plant growth but too much can be a problem for livestock eating the plants; its toxicology is largely tied to its interactions with copper and sulfur [91]. Its concentration in fish is low compared to plants and certain invertebrates [91].

Molybdenum hazards to fish and wildlife are summarized in Eisler's excellent synoptic review [91]. Freshwater fish can regulate molybdenum over a wide range of ambient concentrations [53].

CMFO RESULTS: MOLYBDENUM

Molybdenum was not detected in sediments or fish at any of the sites.

Nickel

(Ni, CAS Number 7440-02-2)

The following is taken from the Contaminant Encyclopedia [8]:

Nickel is a hard, silvery metal heavily used in industrial purposes which is also abundant in the earth's crust [23]. Divalent nickel is the primary aqueous form [23].

Nickel is listed by the Environmental Protection Agency as one of 129 priority pollutants [27], and is considered to be one of the 14 most noxious heavy metals [26]. Nickel is also listed among the 25 hazardous substances thought to pose the most significant potential threat to human health at priority superfund sites [28]. Nickel carbonyl is among the most toxic nickel compounds [26].

Little information is available on the effects of nickel body burdens on fish and wildlife, but experimental doses of nickel have induced cancer in rats, guinea pigs, and rabbits [92]. Some salts of this element are carcinogenic [30]. Nickel is present in asbestos and may play a role in asbestos carcinogenicity [92]. Mixtures of nickel, copper, and zinc produced additive toxicity effects on rainbow trout [5].

Plants take up nickel from soil, groundwater, sewage sludge, fertilizers, and air pollution [26]. Animals take up nickel from industrial sources, contaminated air, contaminated water, and contaminated food [26]. Although nickel occurs naturally in rivers from soil erosion, it is usually elevated at least four times above background levels in most urban settings, with asbestos being one potential source [92]. Other sources include air pollution deposition from burning of fossil fuels, operation of motor vehicles, smelters, electroplating facilities, scrap yards, and various industrial sources [92]. Nickel is also a common contaminant in sludges generated by sewage treatment plants [55]. Nickel is also present in the leachate of some municipal landfills [56].

The Earth's crust contains 0.018% nickel, although the core is believed to be much richer. Meteorites sometimes contain up to 20% nickel. Pure nickel is used in electron tubes and in the galvanic (plating) industry, where many objects must be coated with nickel before they can be chrome plated. Most nickel is used in alloys where high resistance to corrosion is important, such as for chemical-reaction vessels and pump parts. Stainless steel, an alloy of iron and chromium, may contain up to 35% nickel. Special nickel alloys include alnico, cunife, and cunico, used as permanent magnets, and nichrome, which is used as electrical heating elements in many household appliances. Finely divided nickel is used as a catalyst in many reactions, such as the hydrogenation of organic compounds. It is a good catalyst for reactions with carbon monoxide because of the formation of such compounds as nickel carbonyl, a rare example of a compound in which a metal has a zero valence [93].

CMFO RESULTS: NICKEL

All results reported are in dry weight unless stated otherwise.

Nickel was detected in sediments at the six sites that were sampled for sediments. All sediment samples contained nickel. The concentrations ranged from 17.5 ppm to 50.4 ppm. Sediments collected at the Clarence Cannon NWR 330 miles upstream on the Mississippi River had a high of 63.5 ppm.

Nickel was detected in fish at two of the three sites where fish were captured. Nickel was in four of the thirteen fish samples. The concentrations ranged from nondetect to 2.7 ppm. Fish were sampled at four NWR's and the NFH located in Missouri. The highest level was 123 ppm at Neosho NFH.

There is not sufficient data in the literature to make comparisons of sediment or whole body fish concentrations of nickel.

Selenium

(Se, CAS Number 7782-49-2)

The following is taken from the Contaminant Encyclopedia [8]:

Selenium is a nonmetallic element [23]. Selenium is the third member of the chalcogen group of elements of the periodic table, coming after oxygen and sulfur and preceding tellurium [94]. Its atomic number is 34 and its atomic weight 78.96 [94].

Selenium has many teratogenic and toxic impacts upon fish and wildlife at high concentrations [95]. Selenium is listed by the Environmental Protection Agency as one of 129 priority pollutants [27].

Waterfowl feeding on zooplankton or on algae may be more sensitive to selenium contamination than those feeding on seeds [96]. Mallards, cinnamon teal, and pintails, which consume large amounts of seeds are therefore less at risk than gadwalls and Northern shovelers, which consume primarily algae and zooplankton [96]. Using the same criteria, green winged teal and widgeon would be at intermediate risk [96].

Humans require minute quantities of selenium to maintain tissue elasticity and prevent premature aging, muscle pain, and heart disease [16]. The range between insufficient selenium in the diet of animals and too much is narrow, and the effects of either problem can be serious [97]. Effects of too much selenium include birth defects, sterility, and death [97]. In humans, too much selenium has also reportedly caused baldness, loss of nails and teeth, fatigue, and death [16]. Some salts of this element are carcinogenic, yet small amounts of selenium can also act as a protective anticarcinogen [30].

The most important oxidation states are +4 and +6 [94]. The chemical reactions of selenium resemble those of sulfur and are typically nonmetallic in nature [94].

Selenium is a rare element forming only 9×10^{-6} % of the Earth's crust [94]. Plants take up selenium from soil, groundwater, sewage sludge, and air pollution [26]. Animals take up selenium from industrial sources, contaminated air, contaminated water, and contaminated food [26]. Other than areas impacted by agricultural drainage, very high concentrations of selenium in fish and wildlife occur primarily in areas where selenium is naturally high in the soils, where there is an influence of sewage sludge, or where coal fired power plants are present [95] [98].

Man's uses of selenium include photocopying, glass manufacturing, the production of stainless steel, fungicides, lubricants, electronic devices, pigments, dyes, insecticides, and veterinary medicine [99] [17]. Selenium is used in the production of photocells, exposure meters, and solar cells [94]. Selenium also finds extensive application in rectifiers, a result of its ability to convert alternating electric current to direct current [94]. Other applications of the element include its use in the glass industry to decolorize glass, as a photographic toner, as an additive in steel production, and in xerographic reproduction [94]. Selenium dioxide is a good oxidizing agent and is used in certain organic syntheses [94].

CMFO RESULTS: Selenium

All results reported are in dry weight unless stated otherwise.

Selenium was detected in sediments at the six sites that were sampled for sediments. All sediment samples contained selenium. The concentrations ranged from 0.315 ppm to 2.08 ppm. Sediments collected at the Clarence Cannon NWR 330 miles upstream on the Mississippi River had a high of 1.2 ppm.

There is not sufficient data in the literature to make comparisons of sediment concentrations of selenium.

Selenium was detected in fish at all three of the sites where fish were captured. Selenium was in all thirteen of the fish samples. The concentrations ranged from 1.76 to 11.8 ppm. Elevated levels of selenium were detected at all of the three sites where fish were collected. Elevated levels were detected in all but one of the fish samples.

Fish were sampled at four NWR's and the NFH located in Missouri. The highest level was 2.9 ppm at Neosho NFH. The geometric mean for whole fish samples from 109 stations nationwide in the National Contaminant Biomonitoring Program was 0.42 ppm wet weight [2].

Silver

(Ag, CAS Number 7440-22-4)

The following is taken from the Contaminant Encyclopedia [8]:

Silver, atomic number 47, symbol Ag, is a coinage metal with properties closely resembling copper and gold. Its symbol was derived from the Latin argentum, meaning "white and shining," an apt description of this element. The atomic weight of silver is 107.868, and natural silver consists of two stable isotopes: silver-107 (51.82%) and silver-109 (48.18%). The element exhibits bactericidal properties not fully understood, although these are thought to be a result of its ability to absorb oxygen. Colloidal silver is used as an antiseptic, germicide, astringent, and caustic and for water sterilization. Prolonged ingestion of even small quantities may cause silver poisoning, called argyria. Symptoms include a blue coloration of lips and gums as silver is deposited there [100].

Silver is the 68th most abundant element in the Earth's crust and 65th in cosmic abundance. Silver often occurs as a minor constituent in the ores of copper, lead, and zinc. Refinement of these metals yields large quantities of silver (and some gold). Silver is found in minute quantities in seawater. Historically, the principal use of silver has been for coinage, but its unique properties and the demand for more sophisticated manufacturing methods and product uses have relegated coinage to a minor application. By 1970, 28% of all silver used was for photographic processes, and only 8% for coinage. The remaining 64%, although largely used for industrial uses, was also used for art, jewelry, and miscellaneous purposes. Silver's exceedingly high electrical conductance and resistance to oxidation make it valuable in critical electrical contacts, switches, printed circuits, solders, long-lasting batteries, and many forms of electrical and electronic equipment. It is used in bearing alloys for airplanes and diesel engines and recently in some automobiles as well, for the production of mirrors and photochromic lenses, in colloidal form as a catalyst in the manufacture of certain alcohols, as an alloy with cesium in photocells, in the form of silver iodide (AgI) for weather modification. The photographic industry, the largest single user of silver, depends on the chemical reactions of the element. Silver compounds are still occasionally used as disinfectants on mucous membranes, especially to prevent gonorrheal infection in the eyes of newborn babies [100].

CMFO RESULTS: SILVER

Silver was not detected in sediments or fish at any of the sites.

Strontium

(Sr, CAS Number 7440-24-6)

The following is taken from the Contaminant Encyclopedia [8]:

Strontium is a soft, silvery metal with physical and chemical properties similar to those of calcium [101]. It is a fairly common alkaline earth metal [23]. In localities where it is elevated, strontium is an important freshwater quality ion which contributes to water "hardness" [22].

Many radioactive isotopes of strontium are produced in nuclear reactors [101]. Strontium 90 is a radioactive nuclide which is considered to be one of the more undesirable fission products [23]. Highly elevated amounts of radioactive isotopes of strontium are usually the result of nuclear activity. Strontium 90, with a half-life of 28 years, is formed in nuclear explosions; because it accumulates in the bones, it is considered the most dangerous component of radioactive fallout [101].

Body burden issues are not well understood. Although pure strontium does not appear to be very toxic, many strontium compounds are hazardous to fish and wildlife. Strontium chromate is carcinogenic and several strontium compounds are very reactive or explosive [102].

Several strontium compounds are used in pyrotechnics [102].

Allen and Wilson (1991) [76] report that levels of strontium in sediments and biota worldwide were altered after the 1940's by nuclear testing. In animals, strontium is incorporated into bone in place of calcium. Non-radioactive strontium has very low toxicity to aquatic animals and man, but radioactive strontium is extremely toxic. Strontium-90 concentrations were studied in fish of Lake Windermere in England, and it was concluded that there likely has been long-term accumulation of strontium in sediments and biota. Strontium apparently was continuously remobilized and recycled. In the U.S., strontium had a geometric mean concentration of 120 mcg/g in U.S. soils; 200 mcg/g in the west, 53 mcg/g in the east. Strontium is "readily accumulated and retained by fish from either their food or water." However, readily available calcium will limit strontium uptake.

CMFO RESULTS: Strontium

All results reported are in dry weight unless stated otherwise.

Strontium was detected in sediments at the six sites that were sampled for sediments. All sediment samples contained strontium. The concentrations ranged from 5.87 ppm to 61.3 ppm. Sediments collected at the Clarence Cannon NWR 330 miles upstream on the Mississippi River had a high of 62.7 ppm.

Strontium was detected in fish at all three of the sites where fish were captured. Strontium was in all thirteen of the fish samples. The concentrations ranged from 8.51 to 59.6 ppm. Fish were sampled at four NWR's and the NFH located in Missouri. The highest level was 126 ppm at Clarence Cannon NWR.

There is not sufficient data in the literature to make comparisons of sediment or whole body fish concentrations of strontium.

Tin

(Sn, CAS Number 7440-31-5)

The following is taken from the Contaminant Encyclopedia [8]:

Tin is a solid, rather unreactive metal which exhibits two common oxidation states, +2 and +4 [103]. Tin is a heavy metal that is not essential for life; it is widely used in industry, and may be found in relatively high concentrations in air and soil in and around urban industrial areas [104]. No animal teratology studies of tin have been published [104].

Tin hazards to fish and wildlife are summarized in Eisler's excellent synoptic review [105]. Triethyltin and tetraethyltin are especially toxic compounds [26]. Little data is available on tin concentrations in sediment which might be harmful to fish and wildlife, and most of the data which is available relates to tributyltin [33].

CMFO RESULTS: Tin

All results reported are in dry weight unless stated otherwise.

Tin was not detected in sediments at any of the sites.

Tin was detected in fish at one of the three sites where fish were captured. Tin was in one of the thirteen fish samples. The concentrations ranged from nondetect to 5.18 ppm. Fish collected at the Clarence Cannon NWR 330 miles upstream on the Mississippi River had a high of 13.6 ppm.

There is not sufficient data in the literature to make comparisons of sediment or whole body fish concentrations of tin.

Vanadium

(V, CAS Number 1314-62-1)

The following is taken from the Contaminant Encyclopedia [8]:

A transition metal with complex aqueous geochemistry [23]. Vanadium is a bright white metallic chemical element of the first series of transition metals [106]. The outer electronic configuration of vanadium exhibits oxidation states of -1, 0, +1, +2, +3, +4, and +5 in a wide variety of complex ions and coordination complexes [106]. Three oxidation states (+3 to +5) can be stable in water [23].

Natural vanadium consists of two isotopes, V-50 and V-51, the former being slightly radioactive with a half-life of 6×10 to the 15th power years [106]. Seven other radioisotopes of the element have been synthesized [106].

Vanadium and its compounds are toxic [106]. Vanadium is considered to be one of the 14 most noxious heavy metals, but has a much higher bioconcentration potential in mollusks than in fish [26].

Vanadium is found in soil and is deposited in water as a result of fallout from air pollution [26] and is often found in ore along with uranium [23]. Plants take up vanadium from soil, groundwater, surface water, and air pollution [26]. Animals take up vanadium from contaminated air, contaminated water, and contaminated food [26].

The following paragraph summarizing uses and potential sources of vanadium is from reference [106]: Among the 65 or so minerals in which vanadium occurs, the more important sources of the metal include carnotite, patronite, roscoelite, and vanadinite. Other sources of vanadium are in phosphate rock, certain iron ores, and some crude oils in the form of organic complexes. The extraction of vanadium from petroleum ash is a possible future source of the element. Because the metal has good structural strength and a low fission neutron cross-section, it finds extensive application in the nuclear industry. The metal is also used in forming rust-resistant spring and high-speed tool steels; about 80% of the production of vanadium is used to make ferrovanadium or as a steel additive. Vanadium pentoxide is used in ceramics and as a catalyst.

Rompala et. al [5] report that sources of vanadium in the aquatic environment include extraction of iron and titanium, furnace ash from power plants using residual oil fuel, manufacture of steel and glass, textile dyeing, and printing and photographic processed [17] [82].

CMFO RESULTS: Vanadium

All results reported are in dry weight unless stated otherwise.

Vanadium was detected in sediments at the six sites that were sampled for sediments. All sediment samples contained vanadium. The concentrations ranged from 59.1 ppm to 172 ppm. Sediments collected at the Clarence Cannon NWR 330 miles upstream on the Mississippi River had a high of 133 ppm.

Vanadium was detected in fish at two of the three sites where fish were captured. Vanadium was in five of the thirteen fish samples. The concentrations ranged from nondetect to 1.53 ppm. Fish were sampled at four NWR's and the NFH located in Missouri. The highest level was 4.46 ppm at Squaw Creek NWR.

There is not sufficient data in the literature to make comparisons of sediment or whole body fish concentrations of vanadium.

Zinc

(Zn, CAS Number 7440-66-6)

The following is taken from the Contaminant Encyclopedia [8]:

Zinc, the 25th most abundant element, is widely distributed in nature, making up between 0.0005% and 0.02% of the Earth's crust [107]. Zinc is a trace element which can be toxic in some cases but also has some useful physiological functions [24]. Zinc metal normally appears dull gray because of an oxide or basic carbonate coating, but when freshly polished it is bluish white and lustrous [107].

Zinc is listed by the Environmental Protection Agency as one of 129 priority pollutants [27]. Zinc in low to moderate amounts is of very low toxicity in its ordinary compounds and in low concentrations is an essential element in plant and animal life [107]. However, there have been cases of too much zinc causing poisoning in humans as well as fish and wildlife.

Absorption of dietary zinc in higher animals is apparently regulated in part by metal thioneins, low molecular weight proteins containing high levels of cysteine [53]. Freshwater fish can regulate zinc over a wide range of ambient concentrations [53].

Zinc removals by wetlands and detention ponds receiving highway runoff was high [54]. Zinc water concentrations exceeding state standards occurred in 78 % of wetland inlet samples but in only 34 % of outlet samples [54]. Zinc sediment samples were higher in a detention pond than in a downstream wetland [54].

Zinc dissolves in aqueous acids or bases, forming hydrogen gas and zinc ion or zincate ion, respectively [107]. Zinc forms compounds only in the +2 oxidation state [107].

Zinc is one of the most common contaminants associated with urban runoff. Other zinc sources include soil erosion, industrial discharges, pharmaceuticals, and pesticides [108]. In some areas up to 50% of the zinc comes from highway runoff [80]. The national average concentration for zinc in U.S. soils is 300 mg/kg [79]. Zinc is also present in the leachate of some municipal landfills [56] and is a common contaminant in sludges generated by sewage treatment plants [55].

The following paragraph summarizing zinc uses came from reference [107]: Zinc is widely used as a coating to protect iron and steel from corrosion and as a component of useful alloys. The two major uses of zinc metal are (1) to coat iron and steel--a process called galvanizing--to prevent corrosion and (2) as a component of several alloys. An additional 5% to 10% of total zinc production goes into dry-cell battery cans and sheet zinc for photoengraving. Zinc protects iron from rusting because it is the stronger reducing agent of

the two metals. The best-known zinc alloy is brass, which is made of copper with 3% to 45% zinc. The most widely used zinc compounds are the oxide, the sulfide, and the chloride. The oxide is used as a reinforcer in rubber tires, a white paint pigment, a ceramic glaze, and an opaque base in cosmetics, salves, and lotions. The sulfide is used as a phosphor in fluorescent lamps and cathode ray tubes and as a white pigment. The chloride is useful as a soldering flux, a dry-cell battery electrolyte, and a wood preservative. Zinc is a good reducing agent and is used as such in many laboratory applications [107]. Zinc is also used in wet batteries, bearings, dental work, paper defoxing, and in cooling towers (anodic inhibitors)[24].

Zinc in water acts synergistically with copper and ammonia to produce an increased toxic effect on fish [68] [69].

A study in an Arkansas river system showed that macroinvertebrate concentrations were negatively correlated with zinc concentrations but not with concentrations of iron or copper [109].

CMFO RESULTS: ZINC

All results reported are in dry weight unless stated otherwise.

Zinc was detected in sediments at the six sites that were sampled for sediments. All sediment samples contained zinc. The concentrations ranged from 51.5 ppm to 163 ppm. Sediments collected at the Clarence Cannon NWR 330 miles upstream on the Mississippi River had a high of 252 ppm. Elevated levels of zinc were detected at four of the six sites where sediments were collected.

A background level of 120 ppm in sediments from Lake Michigan was reported by the International Joint Commission (IJC) (1988) [38]. EPA sediment classification criteria for chromium lists <90 ppm as nonpolluted (IJC 1982) [39]. Zinc is classed as non-elevated at <80 ppm in Illinois stream sediments [40].

Zinc was detected in fish at all three of the sites where fish were captured. Zinc was in all thirteen of the fish samples. The concentrations ranged from 47.9 to 252 ppm. Elevated levels of zinc were detected at two of the three sites where fish were collected.

Fish were sampled at four NWR's and the NFH located in Missouri. The highest level was 375 ppm at Clarence Cannon NWR. The geometric mean for whole fish samples from 109 stations nationwide in the National Contaminant Biomonitoring Program was 21.7 ppm wet weight [2].

Pesticides and PCB's

For many years pesticides have been one of the most highly publicized classes of environmental pollutants. Chlorinated hydrocarbon insecticides such as DDT, dieldrin, endrin, heptachlor and others, including their metabolites, share three characteristics which cause their use to be of ecological significance. Biologically they are very active and their toxicity, rather than being restricted to insects, extends to a large variety of organisms, including vertebrates. They are chemically very stable and therefore often persist within the environment for years, either in their original state or in a slightly modified state. The non-polar character of these compounds gives them low water solubility and a high lipid solubility, increasing the risk to aquatic organisms [5].

Chlorinated hydrocarbon pesticides (organochlorines) came into wide use in the 1940's. This has resulted in measurable concentrations of organochlorines in practically all surface waters of the world [110]. Pesticides have been identified in soils, sediments, aquifers, lakes, ponds, rivers and streams, as well as the oceans. Antarctic snow and air are contaminated with pesticides [6]. Pesticides have also been found in a wide range of organisms and there is evidence that they contribute to fish diseases [6] [5].

Pesticides may gain access to ground and surface waters through direct application, through percolation and runoff from treated areas, and through drift during application. Additional sources of pesticides in the aquatic environment are pesticide manufacture and associated waste discharges, improper disposal of containers and accidental spills [5].

Similar in structure to some chlorinated pesticides, polychlorinated biphenyls (PCB's) are a group of synthetic compounds with worldwide distribution. They are released into the environment through spills, effluent discharges, incineration, or through disposal in dumps and landfills. Their thermal and chemical stability causes them to be long-term environmental problems. They degrade slowly over a period of many years and are absorbed readily by living organisms, accumulating in lipid tissues and continuing to increase over time, even when exposure levels decrease. This bioaccumulation can cause direct acute impacts. Chronic effects on growth, reproduction, behavior and general health have been reported in fish, birds and mammals. Fish are particularly susceptible since they concentrate PCB's to levels known to cause toxicological effects to piscivorous wildlife [5].

Chlordane

(CAS Number -Aspon, Belt- 57-74-9)

The following is taken from the Contaminant Encyclopedia [8]:

Chlordane is an insecticide which has been severely restricted and cancelled for most uses [61]. The terms "chlordane" or "total chlordane" have been used by various authors and agencies to refer to many different things, including cis-chlordane; cis and trans-chlordane; cis-chlordane and trans-nonachlor; and a combination of cis-chlordane, trans-chlordane, cis-

nonachlor, trans-nonachlor, oxychlordan, heptachlor epoxide, photoheptachlor, and photo-cis-chlordane [111].

Chlordane is listed by the Environmental Protection Agency as one of 129 priority pollutants [27]. Chlordane is classified as a relatively persistent (half-life > 100 days) chemical [112].

It is important to utilize as many chlordane components as possible when trying to gauge the total risk to fish and wildlife, since many of the metabolites are more toxic than some of the parent compounds. For example, oxychlordan is 20 times more toxic than cis or trans-chlordane to rats. Photoheptachlor, heptachlor epoxide oxychlordan, and photo-cis-chlordane are all more toxic to bluegills than are the more commonly reported cis or trans-chlordane [111].

Cis-chlordane comprises about 19% of technical chlordane.

Trans-chlordane comprises about 24% of technical chlordane.

Nonachlor (trans-Nonachlor) isomers make up about 7% of technical chlordane. Trans-nonachlor is one of the few compounds found in fish which is supertoxic to aquatic invertebrates [113].

The organochlorine insecticide heptachlor (Heptamul, CAS Number 76-44-8) is rapidly metabolized into heptachlor epoxide by many organisms. Both heptachlor and heptachlor epoxide are listed by the Environmental Protection Agency among 129 priority pollutants [27]. Heptachlor was formerly widely used as a soil insecticide, crop pesticide, fire ant killer, and termiticide. It is classified as a relatively persistent (half-life > 100 days) chemical [112].

Heptachlor is also a minor (<10%), but relatively toxic, component of technical chlordane. Although some authors have concluded that most environmental residues of heptachlor epoxide originated in the use of heptachlor, others have concluded that lethal residues in birds originated from technical chlordane [111].

The insecticide heptachlor is rapidly metabolized into heptachlor epoxide by many organisms. Both heptachlor and heptachlor epoxide are listed by the Environmental Protection Agency among 129 priority pollutants [27]. Heptachlor was formerly widely used as a soil insecticide, crop pesticide, fire ant killer, and termiticide. Heptachlor has a very high carcinogenic potency [114].

Heptachlor is also a minor (<10%), but relatively toxic, component of technical chlordane. Although some authors have concluded that most environmental residues of heptachlor epoxide originated in the use of heptachlor, others have concluded that lethal residues in birds originated from technical chlordane [111].

CMFO RESULTS: CHLORDANE TOTAL

All results reported are in dry weight unless stated otherwise.

Total chlordane was detected in fish at all three of the sites where fish were captured. The concentrations ranged from non-detect to 0.42 ppm wet weight.

Fish were sampled at four NWR's and the NFH located in Missouri. The highest level was 0.24 ppm wet weight at Neosho NFH.

DDX

(DDD, DDE, DDT)

DDD (p,p' DDD CAS Number 72-54-8)

DDE (p,p' DDE CAS Number 72-55-9)

DDT (p,p' DDT, CAS Number 50-29-3)

The following is taken from the Contaminant Encyclopedia [8]:

DDD was formerly marketed as the pesticide TDE. Like DDE, p, p' DDD (DDD) is a breakdown product of DDT. All registered pesticides containing DDD as an active ingredient have been cancelled [61]. DDD is listed by the Environmental Protection Agency as one of 129 priority pollutants [27].

DDE is a breakdown product of DDT, an insecticide which had widespread use before being banned in the U.S. in 1972. DDE effectively inhibits the ability of birds to provide sufficient calcium deposits for their eggs, producing fragile shells and a high percentage of nested eggs that break prematurely [115].

DDE is listed by the Environmental Protection Agency as one of 129 priority pollutants [27]. DDE has been detected in fish eating birds in concentrations which may pose a problem for predatory bald eagles [116].

Most, not all, products containing DDT have been cancelled [61]. Agricultural use of DDT has been banned in the U.S. since 1972 and most remaining residues have presumably broken down into DDE, DDD, and other chemicals.

CMFO RESULTS: DDD, DDE, DDT TOTAL (DDX)

All results reported are in dry weight unless stated otherwise.

DDX was detected in fish at all three of the sites where fish were captured. The concentrations ranged from 0.02 ppm to 0.29 ppm wet weight. Elevated levels of DDX was detected at one of the three sites where fish were collected.

Fish were sampled at four NWR's and the NFH located in Missouri. The highest level was 0.15 ppm wet weight at Neosho NFH. The geometric mean for whole fish samples from 109 stations nationwide in the National Contaminant Biomonitoring Program was 0.20 ppm wet weight for DDE and 0.07 ppm wet weight DDD [2].

Dieldrin

(CAS Number -Alvit- 60-57-1)

The following is taken from the Contaminant Encyclopedia [8]:

Since 1974, use of the insecticide dieldrin (and aldrin, which breaks down into dieldrin) has been restricted to termite control and non-food plant treatment [5] [61]. Dieldrin is listed by the Environmental Protection Agency as one of 129 priority pollutants [27]. Dieldrin is also listed among the 25 hazardous substances thought to pose the most significant potential threat to human health at priority superfund sites [28]. It is classified as a relatively persistent (half-life > 100 days) chemical [112].

Dieldrin produces liver tumors in mice, is toxic to fish, is very persistent, and bioaccumulates in fish [5].

Body burdens of dieldrin decrease a fish's ability to tolerate ammonia, a common toxic compound at sites downstream of large sewage treatment plants [5].

CMFO RESULTS: DIELDRIN

All results reported are in dry weight unless stated otherwise.

Dieldrin was detected in fish at all three of the sites where fish were captured. The concentrations ranged from non-detect to 0.05 ppm wet weight. Elevated levels of dieldrin were detected at one of the three sites where fish were collected.

Fish were sampled at four NWR's and the NFH located in Missouri. The highest level was 0.21 ppm wet weight at Swan Lake NWR. The geometric mean for whole fish samples from 109 stations nationwide in the National Contaminant Biomonitoring Program was 0.04 ppm wet weight [2].

PCBs

(Polychlorinated Biphenyls, CAS Number 53469-21-9)

The following is taken from the Contaminant Encyclopedia [8]:

Due to their potency and widespread distribution, PCBs are one of the few contaminants for which we have several action and alert levels with which to compare our results. PCBs are very stable compounds which belong to a group of chemicals known as the arene halides, considered by some to be the most hazardous group of chemicals typically found in fish [113].

In 1972, Monsanto restricted their distribution to closed systems such as transformers, capacitors, and heat transformers. PCBs are so widespread that trace amounts have been detected in mothers' milk [35].

Liver damage, carcinogenic effects, birth defects, and reproductive problems have been documented for PCBs in mammals such as rodents and monkeys [117] [118] [5]. PCBs have been found to be carcinogenic in rats [119] [120] and mice [119]. In minks and monkeys, some PCB mixtures have been found to cause spontaneous abortions [120]. PCB mixtures have also been shown to be fetotoxic in rodents, causing resorptions [120].

Drinking water concentrations of two PCB compounds (PCB-1254 or CAS Number 11096-69-1 and PCB-1260 or CAS Number 11096-82-5) even lower than a concentration commonly used as a detection limit (1 ug/L) may result in an unacceptable human cancer risk [121]

Some experts believe that many of the mammalian or human effects which have ascribed to PCBs may actually be caused by chlorinated dibenzofurans [120]. Dibenzofurans are very hazardous chemicals which are closely related to PCBs and often occur as contaminants in PCB mixtures [120].

Six PCB compounds are listed by the Environmental Protection Agency among 129 priority pollutants [27]. PCBs are also listed among the 25 hazardous substances thought to pose the most significant potential threat to human health at superfund sites on the national priority list [28].

Fish and other aquatic life bioaccumulate PCBs through the gills and through the foodchain [122]. Due to their ability to biomagnify (increase in concentration as they move to higher levels in the food chain), contaminants such as PCBs, mercury, and chlordane are particularly hazardous to predators such as bass, sunfish, river otters, herons, egrets, and eagles. Predatory fish and wildlife are at risk since such a large percentage of their diet consists of other species of fish and wildlife.

The significant presence of biomagnifying contaminants such as PCBs is of particular concern in areas frequented by predatory endangered species such as bald eagles. Eagles are long-lived and predatory, feeding primarily on fish, waterfowl, and carrion. Bottom feeding fish, including channel catfish, carp, and flathead catfish, make up a significant portion of an eagle's diet [98]. PCBs have been detected in fish eating birds in concentrations which may pose a problem for predatory bald eagles [116]. Also, carrion available during fish kills

increase the risk from PCB contamination, since eagles may be eating larger fish (which typically have higher levels of PCBs) than normal.

Birds of prey such as eagles are susceptible to PCB effects on reproductive hormones [123], lowered sperm counts [124], decreased reproductive success [125], less vigorous behavior [125], and hatching failure [126]. Many of the effects documented above for raptors may also be occurring in other types of birds, although specific information is lacking on most species. In various fish species, exposure to PCBs has been shown to reduce reproductive success [117] or increase susceptibility to disease [52]. Thus, excessive body burdens of PCBs in prey species, particularly in combination with excessive body burdens of other contaminants known to be harmful to predators, may be adversely impacting predatory species of fish in areas polluted by PCBs.

Bioturbation (stirring) of bottom sediments by fish increases desorption of PCBs from sediments and subsequent bioaccumulation from the water [52].

PCBs have been widely used as lubricants, insulators, and coolants [122]. Other known sources of PCBs include electrical transformers, capacitors, heat transfer fluids, railroad yards, electrical utilities, oils used for dust suppression, grain elevators, packing plants, scrap and salvage operations including oil and metal recyclers, general manufacturing facilities, electrical equipment in office or industrial buildings, and some types of high tech electronics manufacturing facilities [117] [127]. Prior to 1971, PCBs were also used in carbonless copy paper, hydraulic fluid, and paints [120]. As a result of current regulatory restrictions, contaminated fish are the primary food source of PCBs for humans today [120].

In storm drains of downtown areas of large cities, a frequently suspected source of PCBs is large electrical transformers. Fires can rupture transformers. The Environmental Protection Agency has concluded that fires in transformers containing PCBs pose risks to humans and the environment and is continuing a gradual reduction of PCB use in transformers [128]. Combustion of PCB contaminated oils can produce dibenzofurans and other hazardous chemicals. Dibenzofurans are already present as contaminants in some PCB mixtures, so fires would provide an additional source. Combustion of (formerly common) transformer mixtures of PCBs and trichlorobenzene also produces dioxins.

Some transformers rupture in transportation accidents, and storms often knock down power line transformers and rupture them [129]. Storm water transport of PCB-contaminated soils or oils is one potential mechanism by which PCBs could move from transformer sites into storm drains.

PCBs are a good example of urban runoff contaminants which may be more effectively reduced by simple efforts to find and eliminate sources and contaminated soils at spill sites rather than by spending more money to further reduce contaminant concentrations in effluents of large sewage treatment plants.

Municipal landfills are an additional potential source of PCBs in urban areas. The potential for PCB contamination of rivers from this source is increased by high concentrations of electronic manufacturing facilities, the previous lack of controls for dumping industrial items in municipal landfills [114], and the existence of many municipal landfills located within the floodplain. In addition to the potential for leachate to enter the river from adjacent landfills, underground flow connections in sandy soils and bank erosion provide additional potential pathways for transport of PCBs or PCB-contaminated soils from the landfills to the river.

CMFO RESULTS: PCB's TOTAL

All results reported are in dry weight unless stated otherwise.

PCB's were detected in fish at all three of the sites where fish were captured. The concentrations ranged from non-detect to 0.8 ppm wet weight. Elevated levels of PCB's were detected at one of the three sites where fish were collected.

Fish were sampled at four NWR's and the NFH located in Missouri. The highest level was 0.7 ppm wet weight at Clarence Cannon NWR. The geometric mean for whole fish samples from 109 stations nationwide in the National Contaminant Biomonitoring Program was 0.39 ppm wet weight [2].

Toxaphene

(CAS Number -Attac, Vertac, Camphechlor- 8001-35-2)

The following is taken from the Contaminant Encyclopedia [8]:

A restricted [61] use insecticide, rodenticide, and acaricide. The label must state the product is toxic to fish, birds, and other wildlife [61]. Among other impacts, toxaphene has been shown to cause deformities in the backbone of some fish species [130].

Toxaphene hazards to fish and wildlife are summarized in Eisler's excellent synoptic review [131].

The Fish and Wildlife Service, in a 1989 formal Section 7 consultation with EPA, has determined jeopardy for four federally-listed threatened or endangered species of birds as a result of this chemical's potential effect on the listed species and/or on food items of importance to the listed species [132] [133]. EPA also determined the chemical "may affect" some other bird and fish species in certain circumstances [133]. Of course, the above-mentioned Section 7 determinations were limited in scope to certain assumptions and chemical use patterns, so it should not be inferred from the above statements that various other taxa or other listed species would not be impacted by this chemical under certain circumstances.

CMFO RESULTS: TOXAPHENE

All results reported are in dry weight unless stated otherwise.

Toxaphene was detected in fish at one of the sites where fish were captured. The concentrations ranged from non-detect to 0.46 ppm wet weight. This is an elevated level of toxaphene.

Fish were sampled at four NWR's and the NFH located in Missouri. The highest level was 0.61 ppm wet weight at Swan Lake NWR. The geometric mean for whole fish samples from 109 stations nationwide in the National Contaminant Biomonitoring Program was 0.14 ppm wet weight [2].

Conclusions and Recommendations

These results were compared to the two data sets indicative background levels in fish and sediments. Additional information on the data sets is in the Discussion section under the subheading Contaminant Concentration Comparisons. The original documents relating to the data sets are listed in the Reference section [38] [39] [40]. The results were also discussed with various Service experts. Based upon the limited sampling in this survey, elevated levels are indicated in arsenic, cadmium, chromium, copper, lead, mercury, selenium, zinc, dieldrin, total PCB's, and toxaphene.

The highest elevated level recorded during this survey for each of these contaminants in sediments is arsenic 20.0 ppm, cadmium 1.17 ppm, chromium 80.1 ppm, copper 48.0 ppm, lead 47.0 ppm, mercury 0.0896 ppm, zinc 163.0 ppm and in fish is cadmium 0.394 ppm, chromium 1.24 ppm, copper 11.6 ppm, lead 5.12 ppm, mercury 1.73 ppm, selenium 11.8 ppm, zinc 252.0 ppm, dieldrin 0.05 ppm, total PCB's 0.08 ppm, and toxaphene 0.46 ppm (all of these results are in dry weight except dieldrin, PCB's, and toxaphene). Refer to the Results section of this document for contaminant level comparisons. Also see Appendix G for a graphic comparison of these levels to other FWS facilities in Missouri.

This report summarizes the results of contaminant samples taken in April and May of 1990 at selected locations within the proposed New Madrid NWR. A companion report will address the biological implications of these results, especially as they relate to the impact analysis and decision making in the pending Environmental Impact Statement for the proposed acquisition. That report will also summarize contaminant data available from other sources that are relevant to the proposed refuge.

TJN:tn:1124nenewmac

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